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(54) Title: INHIBITORS OF HISTONE DEACETYLASE

(57) Abstract: The invention relates to the inhibition of histone deacetylase. The invention provides compounds and methods for inhibiting histone deacetylase enzymatic activity. The invention also provides compositions and methods for treating cell proliferative diseases and conditions.

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# INHIBITORS OF HISTONE DEACETYLASE

## BACKGROUND OF THE INVENTION

### 10 Field of the Invention

This invention relates to the inhibition of histone deacetylase. More particularly, the invention relates to compounds and methods for inhibiting histone deacetylase enzymatic activity.

### Summary of the Related Art

15 In eukaryotic cells, nuclear DNA associates with histones to form a compact complex called chromatin. The histones constitute a family of basic proteins which are generally highly conserved across eukaryotic species. The core histones, termed H2A, H2B, H3, and H4, associate to form a protein core. DNA winds around this protein core, with the basic amino acids of the histones  
20 interacting with the negatively charged phosphate groups of the DNA. Approximately 146 base pairs of DNA wrap around a histone core to make up a nucleosome particle, the repeating structural motif of chromatin.

Csordas, *Biochem. J.*, 286: 23-38 (1990) teaches that histones are subject to posttranslational acetylation of the  $\epsilon$ -amino groups of N-terminal lysine  
25 residues, a reaction that is catalyzed by histone acetyl transferase (HAT1). Acetylation neutralizes the positive charge of the lysine side chain, and is thought to impact chromatin structure. Indeed, Taunton *et al.*, *Science*, 272: 408-411 (1996), teaches that access of transcription factors to chromatin templates is enhanced by histone hyperacetylation. Taunton *et al.* further teaches that an  
30 enrichment in underacetylated histone H4 has been found in transcriptionally silent regions of the genome.

Histone acetylation is a reversible modification, with deacetylation being catalyzed by a family of enzymes termed histone deacetylases (HDACs). Grozinger *et al.*, *Proc. Natl. Acad. Sci. USA*, 96: 4868-4873 (1999), teaches that

5 HDACs may be divided into two classes, the first represented by yeast Rpd3-like proteins, and the second represented by yeast Hda1-like proteins. Grozinger *et al.* also teaches that the human HDAC1, HDAC2, and HDAC3 proteins are members of the first class of HDACs, and discloses new proteins, named HDAC4, HDAC5, and HDAC6, which are members of the second class of  
10 HDACs. Kao *et al.*, *Genes & Dev.*, **14**: 55-66 (2000), discloses HDAC7, a new member of the second class of HDACs. Van den Wyngaert, *FEBS*, **478**: 77-83 (2000) discloses HDAC8, a new member of the first class of HDACs.

Richon *et al.*, *Proc. Natl. Acad. Sci. USA*, **95**: 3003-3007 (1998), discloses that HDAC activity is inhibited by trichostatin A (TSA), a natural product isolated  
15 from *Streptomyces hygroscopicus*, and by a synthetic compound, suberoylanilide hydroxamic acid (SAHA). Yoshida and Beppu, *Exper. Cell Res.*, **177**: 122-131 (1988), teaches that TSA causes arrest of rat fibroblasts at the G<sub>1</sub> and G<sub>2</sub> phases of the cell cycle, implicating HDAC in cell cycle regulation. Indeed, Finnin *et al.*, *Nature*, **401**: 188-193 (1999), teaches that TSA and SAHA inhibit cell growth,  
20 induce terminal differentiation, and prevent the formation of tumors in mice.

These findings suggest that inhibition of HDAC activity represents a novel approach for intervening in cell cycle regulation and that HDAC inhibitors have great therapeutic potential in the treatment of cell proliferative diseases or conditions. To date, only a few inhibitors of histone deacetylase are known in  
25 the art. There is thus a need to identify additional HDAC inhibitors and to identify the structural features required for potent HDAC inhibitory activity.

### BRIEF SUMMARY OF THE INVENTION

The invention provides compounds and methods for treating cell proliferative diseases. In particular, the invention provides new inhibitors of  
30 histone deacetylase enzymatic activity.

In a first aspect, therefore, the invention provides novel inhibitors of histone deacetylase. In one embodiment, the novel inhibitors of histone deacetylase are represented by formula (1):



wherein

Cy is cycloalkyl, aryl, heteroaryl, or heterocyclyl, any of which may be optionally substituted;

10 L<sup>1</sup> is  $-(\text{CH}_2)_m\text{-W-}$ , where m is 0, 1, 2, 3, or 4, and W is selected from the group consisting of  $-\text{C(O)NH-}$ ,  $-\text{S(O)}_2\text{NH-}$ ,  $-\text{NHC(O)-}$ ,  $-\text{NHS(O)}_2\text{-}$ , and  $-\text{NH-C(O)-NH-}$ ;

Ar is arylene, wherein said arylene optionally may be additionally substituted and optionally may be fused to an aryl or heteroaryl ring, or to a saturated or partially unsaturated cycloalkyl or heterocyclic ring, any of which  
15 may be optionally substituted;

Y<sup>1</sup> is a chemical bond or a straight- or branched-chain saturated alkylene, wherein said alkylene may be optionally substituted; and

Z is selected from the group consisting of aniliny, pyridyl, thiadiazolyl, and  $-\text{O-M}$ , M being H or a pharmaceutically acceptable cation;

20 provided that when L<sup>1</sup> is  $-\text{C(O)NH-}$ , Y<sup>1</sup> is  $-(\text{CH}_2)_n\text{-}$ , n being 1, 2, or 3, and Z is  $-\text{O-M}$ , then Cy is not aminophenyl, dimethylaminophenyl, or hydroxyphenyl; and further provided that when L<sup>1</sup> is  $-\text{C(O)NH-}$  and Z is pyridyl, then Cy is not substituted indoliny.

25 In a second embodiment, the novel inhibitors of histone deacetylase are represented by formula (2):



wherein

30 Cy is cycloalkyl, aryl, heteroaryl, or heterocyclyl, any of which may be optionally substituted, provided that Cy is not a (spirocycloalkyl)heterocyclyl;

L<sup>2</sup> is C<sub>1</sub>-C<sub>6</sub> saturated alkylene or C<sub>2</sub>-C<sub>6</sub> alkenylene, wherein the alkylene or alkenylene optionally may be substituted, provided that L<sup>2</sup> is not  $-\text{C(O)-}$ , and wherein one of the carbon atoms of the alkylene optionally may be replaced by a



5 heteroatom moiety selected from the group consisting of O; NR', R' being alkyl, acyl, or hydrogen; S; S(O); or S(O)<sub>2</sub>;

Ar is arylene, wherein said arylene optionally may be additionally substituted and optionally may be fused to an aryl or heteroaryl ring, or to a saturated or partially unsaturated cycloalkyl or heterocyclic ring, any of which  
10 may be optionally substituted; and

Y<sup>2</sup> is a chemical bond or a straight- or branched-chain saturated alkylene, which may be optionally substituted, provided that the alkylene is not substituted with a substituent of the formula -C(O)R wherein R comprises an α-amino acyl moiety; and

15 Z is selected from the group consisting of aniliny, pyridyl, thiadiazolyl, and -O-M, M being H or a pharmaceutically acceptable cation;

provided that when the carbon atom to which Cy is attached is oxo substituted, then Cy and Z are not both pyridyl.

20 In a third embodiment, the novel inhibitors of histone deacetylase are represented by formula (3):



wherein

25 Cy is cycloalkyl, aryl, heteroaryl, or heterocyclyl, any of which may be optionally substituted, provided that Cy is not a (spirocycloalkyl)heterocyclyl;

L<sup>3</sup> is selected from the group consisting of

(a) -(CH<sub>2</sub>)<sub>m</sub>-W-, where m is 0, 1, 2, 3, or 4, and W is selected from the group consisting of -C(O)NH-, -S(O)<sub>2</sub>NH-, -NHC(O)-, -NHS(O)<sub>2</sub>-, and -NH-C(O)-NH-; and

30 (b) C<sub>1</sub>-C<sub>6</sub> alkylene or C<sub>2</sub>-C<sub>6</sub> alkenylene, wherein the alkylene or alkenylene optionally may be substituted, provided that L<sup>3</sup> is not -C(O)-, and wherein one of the carbon atoms of the alkylene optionally may be replaced by O; NR', R' being alkyl, acyl, or hydrogen; S; S(O); or S(O)<sub>2</sub>;

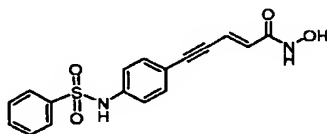
5 Ar is arylene, wherein said arylene optionally may be additionally substituted and optionally may be fused to an aryl or heteroaryl ring, or to a saturated or partially unsaturated cycloalkyl or heterocyclic ring, any of which may be optionally substituted; and

Y<sup>3</sup> is C<sub>2</sub> alkenylene or C<sub>2</sub> alkynylene, wherein one or both carbon atoms of  
10 the alkenylene optionally may be substituted with alkyl, aryl, alkaryl, or aralkyl; and

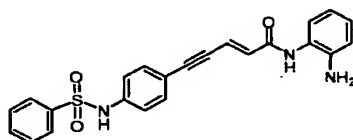
Z is selected from the group consisting of anilinyll, pyridyl, thiadiazolyl, and -O-M, M being H or a pharmaceutically acceptable cation;

provided that when Cy is unsubstituted phenyl, Ar is not phenyl wherein  
15 L<sup>3</sup> and Y<sup>3</sup> are oriented *ortho* or *meta* to each other.

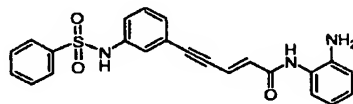
In a fourth embodiment, the novel histone deacetylase inhibitor is selected from the group represented by formulae (4)-(6):



(4)



(5)



(6)

In a second aspect, the invention provides a pharmaceutical composition comprising an inhibitor of histone deacetylase represented by any one of  
25 formulae (1)-(6) and a pharmaceutically acceptable carrier, excipient, or diluent.

5 In a third aspect, the invention provides methods for inhibiting histone deacetylase in a cell, comprising contacting a cell in which inhibition of histone deacetylase is desired with an inhibitor of histone deacetylase. In a first embodiment according to this aspect of the invention, the inhibitor of histone deacetylase is represented by formula (1):



wherein

Cy is cycloalkyl, aryl, heteroaryl, or heterocyclyl, any of which may be optionally substituted;

15 L<sup>1</sup> is -(CH<sub>2</sub>)<sub>m</sub>-W-, where m is 0, 1, 2, 3, or 4, and W is selected from the group consisting of -C(O)NH-, -S(O)<sub>2</sub>NH-, -NHC(O)-, -NHS(O)<sub>2</sub>-, and -NH-C(O)-NH-;

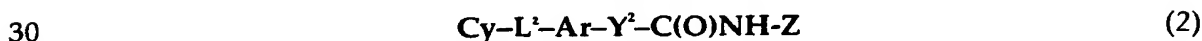
20 Ar is arylene, wherein said arylene optionally may be additionally substituted and optionally may be fused to an aryl or heteroaryl ring, or to a saturated or partially unsaturated cycloalkyl or heterocyclic ring, any of which may be optionally substituted;

Y<sup>1</sup> is a chemical bond or a straight- or branched-chain saturated alkylene, wherein said alkylene may be optionally substituted; and

Z is selected from the group consisting of aniliny, pyridyl, 2-thioxo-1,3,4-thiadiazol-2-yl, and -O-M, M being H or a pharmaceutically acceptable cation;

25 provided that when L<sup>1</sup> is -C(O)NH-, Y is -(CH<sub>2</sub>)<sub>n</sub>-, n being 1, 2, or 3, and Z is -O-M, then Cy is not aminophenyl, dimethylaminophenyl, or hydroxyphenyl.

In a second embodiment according to this aspect of the invention, the inhibitor of histone deacetylase is represented by formula (2)



wherein

Cy is cycloalkyl, aryl, heteroaryl, or heterocyclyl, any of which may be optionally substituted;

5 L<sup>2</sup> is C<sub>1</sub>-C<sub>6</sub> saturated alkylene or C<sub>2</sub>-C<sub>6</sub> alkenylene, either of which may be optionally substituted;

Ar is arylene, wherein said arylene optionally may be additionally substituted and optionally may be fused to an aryl or heteroaryl ring, or to a saturated or partially unsaturated cycloalkyl or heterocyclic ring, any of which  
10 may be optionally substituted; and

Y<sup>2</sup> is a chemical bond or a straight- or branched-chain saturated alkylene, which may be optionally substituted, provided that the alkylene is not substituted with a substituent of the formula -C(O)R wherein R comprises an  $\alpha$ -amino acyl moiety; and

15 Z is selected from the group consisting of aniliny, pyridyl, 2-thioxo-1,3,4-thiadiazol-2-yl, and -O-M, M being H or a pharmaceutically acceptable cation.

In a third embodiment according to this aspect of the invention, the inhibitor of histone deacetylase is represented by formula (3):

20 
$$\text{Cy-L}^3\text{-Ar-Y}^3\text{-C(O)NH-Z} \quad (3)$$

wherein

Cy is cycloalkyl, aryl, heteroaryl, or heterocyclyl, any of which may be optionally substituted, provided that Cy is not a (spirocycloalkyl)heterocyclyl;

L<sup>3</sup> is selected from the group consisting of

25 (a)  $-(\text{CH}_2)_m\text{-W-}$ , where m is 0, 1, 2, 3, or 4, and W is selected from the group consisting of -C(O)NH-, -S(O)<sub>2</sub>NH-, -NHC(O)-, -NHS(O)<sub>2</sub>-, and -NH-C(O)-NH-; and

(b) C<sub>1</sub>-C<sub>6</sub> alkylene or C<sub>2</sub>-C<sub>6</sub> alkenylene, wherein the alkylene or alkenylene optionally may be substituted, provided that L<sup>3</sup> is not -C(O)-, and wherein one of the carbon atoms of the alkylene optionally may be  
30 replaced by O; NR', R' being alkyl, acyl, or hydrogen; S; S(O); or S(O)<sub>2</sub>;

Ar is arylene, wherein said arylene optionally may be additionally substituted and optionally may be fused to an aryl or heteroaryl ring, or to a

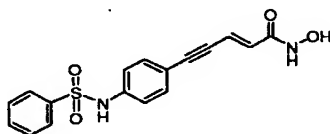
5 saturated or partially unsaturated cycloalkyl or heterocyclic ring, any of which may be optionally substituted; and

$Y^3$  is  $C_2$  alkenylene or  $C_2$  alkynylene, wherein one or both carbon atoms of the alkenylene optionally may be substituted with alkyl, aryl, alkaryl, or aralkyl; and

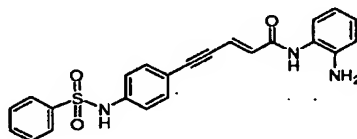
10 Z is selected from the group consisting of aniliny, pyridyl, thiadiazolyl, and -O-M, M being H or a pharmaceutically acceptable cation;

provided that when Cy is unsubstituted phenyl, Ar is not phenyl wherein  $L^3$  and  $Y^3$  are oriented *ortho* or *meta* to each other.

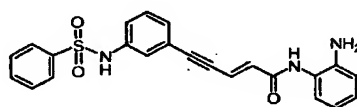
15 In a fourth embodiment according to this aspect of the invention, the novel histone deacetylase inhibitor is selected from the group represented by formulae (4)-(6):



(4)



(5)



(6)

20

### DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

The invention provides compounds and methods for inhibiting histone deacetylase enzymatic activity. The invention also provides compositions and methods for treating cell proliferative diseases and conditions. The patent and scientific literature referred to herein establishes knowledge that is available to

25

5 those with skill in the art. The issued patents, applications, and references that are cited herein are hereby incorporated by reference to the same extent as if each was specifically and individually indicated to be incorporated by reference. In the case of inconsistencies, the present disclosure will prevail.

For purposes of the present invention, the following definitions will be  
10 used:

As used herein, the terms "histone deacetylase" and "HDAC" are intended to refer to any one of a family of enzymes that remove acetyl groups from the  $\epsilon$ -amino groups of lysine residues at the N-terminus of a histone. Unless otherwise indicated by context, the term "histone" is meant to refer to any  
15 histone protein, including H1, H2A, H2B, H3, H4, and H5, from any species. Preferred histone deacetylases include class I and class II enzymes. Preferably the histone deacetylase is a human HDAC, including, but not limited to, HDAC-1, HDAC-2, HDAC-3, HDAC-4, HDAC-5, HDAC-6, HDAC-7, and HDAC-8. In some other preferred embodiments, the histone deacetylase is derived from a  
20 protozoal or fungal source.

The term "histone deacetylase inhibitor" or "inhibitor of histone deacetylase" is used to identify a compound having a structure as defined herein, which is capable of interacting with a histone deacetylase and inhibiting its enzymatic activity. Inhibiting histone deacetylase enzymatic activity means  
25 reducing the ability of a histone deacetylase to remove an acetyl group from a histone. In some preferred embodiments, such reduction of histone deacetylase activity is at least about 50%, more preferably at least about 75%, and still more preferably at least about 90%. In other preferred embodiments, histone deacetylase activity is reduced by at least 95% and more preferably by at least  
30 99%.

Preferably, such inhibition is specific, *i.e.*, the histone deacetylase inhibitor reduces the ability of a histone deacetylase to remove an acetyl group from a histone at a concentration that is lower than the concentration of the inhibitor that is required to produce another, unrelated biological effect. Preferably, the

5 concentration of the inhibitor required for histone deacetylase inhibitory activity is at least 2-fold lower, more preferably at least 5-fold lower, even more preferably at least 10-fold lower, and most preferably at least 20-fold lower than the concentration required to produce an unrelated biological effect.

The term "alkyl" as employed herein refers to straight and branched chain  
10 aliphatic groups having from 1 to 12 carbon atoms, preferably 1-8 carbon atoms, and more preferably 1-6 carbon atoms, which may be optionally substituted with one, two or three substituents. Unless otherwise apparent from context, the term "alkyl" is meant to include saturated, unsaturated, and partially  
15 unsaturated aliphatic groups. When unsaturated groups are particularly intended, the terms "alkenyl" or "alkynyl" will be used. When only saturated groups are intended, the term "saturated alkyl" will be used. Preferred saturated alkyl groups include, without limitation, methyl, ethyl, propyl, isopropyl, butyl, isobutyl, *sec*-butyl, *tert*-butyl, pentyl, and hexyl.

An "alkylene" group is an alkyl group, as defined hereinabove, that is  
20 positioned between and serves to connect two other chemical groups. Preferred alkylene groups include, without limitation, methylene, ethylene, propylene, and butylene.

The term "cycloalkyl" as employed herein includes saturated and partially  
25 unsaturated cyclic hydrocarbon groups having 3 to 12 carbons, preferably 3 to 8 carbons, and more preferably 3 to 6 carbons, wherein the cycloalkyl group additionally may be optionally substituted. Preferred cycloalkyl groups include, without limitation, cyclopropyl, cyclobutyl, cyclopentyl, cyclopentenyl, cyclohexyl, cyclohexenyl, cycloheptyl, and cyclooctyl.

An "aryl" group is a  $C_6$ - $C_{10}$  aromatic moiety comprising one to three  
30 aromatic rings, which may be optionally substituted. Preferably, the aryl group is a  $C_6$ - $C_{10}$  aryl group. Preferred aryl groups include, without limitation, phenyl, naphthyl, anthracenyl, and fluorenyl. An "aralkyl" or "arylalkyl" group comprises an aryl group covalently linked to an alkyl group, either of which may independently be optionally substituted or unsubstituted. Preferably, the

5 aralkyl group is (C<sub>1</sub>-C<sub>6</sub>)alk(C<sub>6</sub>-C<sub>10</sub>)aryl, including, without limitation, benzyl, phenethyl, and naphthylmethyl. An "alkaryl" or "alkylaryl" group is an aryl group having one or more alkyl substituents. Examples of alkaryl groups include, without limitation, tolyl, xylyl, mesityl, ethylphenyl, *tert*-butylphenyl, and methylnaphthyl.

10 An "arylene" group is an aryl group, as defined hereinabove, that is positioned between and serves to connect two other chemical groups. Preferred arylene groups include, without limitation, phenylene and naphthylene. The term "arylene" is also meant to include heteroaryl bridging groups, including, but not limited to, benzothienyl, benzofuryl, quinolyl, isoquinolyl, and indolyl.

15 A "heterocyclyl" or "heterocyclic" group is a ring structure having from about 3 to about 8 atoms, wherein one or more atoms are selected from the group consisting of N, O, and S. The heterocyclic group may be optionally substituted on carbon at one or more positions. The heterocyclic group may also independently be substituted on nitrogen with alkyl, aryl, aralkyl, alkylcarbonyl, 20 alkylsulfonyl, arylcarbonyl, arylsulfonyl, alkoxy carbonyl, aralkoxy carbonyl, or on sulfur with oxo or lower alkyl. Preferred heterocyclic groups include, without limitation, epoxy, aziridinyl, tetrahydrofuranyl, pyrrolidinyl, piperidinyl, piperazinyl, thiazolidinyl, oxazolidinyl, oxazolidinonyl, and morpholino. In certain preferred embodiments, the heterocyclic group is fused 25 to an aryl or heteroaryl group. Examples of such fused heterocycles include, without limitation, tetrahydroquinoline and dihydrobenzofuran.

As used herein, the term "heteroaryl" refers to groups having 5 to 14 ring atoms, preferably 5, 6, 9, or 10 ring atoms; having 6, 10, or 14  $\pi$  electrons shared in a cyclic array; and having, in addition to carbon atoms, between one and 30 about three heteroatoms selected from the group consisting of N, O, and S. Preferred heteroaryl groups include, without limitation, thienyl, benzothienyl, furyl, benzofuryl, dibenzofuryl, pyrrolyl, imidazolyl, pyrazolyl, pyridyl, pyrazinyl, pyrimidinyl, indolyl, quinolyl, isoquinolyl, quinoxaliny, tetrazolyl, oxazolyl, thiazolyl, and isoxazolyl.



5 As employed herein, a "substituted" alkyl, cycloalkyl, aryl, heteroaryl, or heterocyclic group is one having between one and about four, preferably between one and about three, more preferably one or two, non-hydrogen substituents. Suitable substituents include, without limitation, halo, hydroxy, nitro, haloalkyl, alkyl, alkaryl, aryl, aralkyl, alkoxy, aryloxy, amino, acylamino, 10 alkylcarbamoyl, arylcarbamoyl, aminoalkyl, alkoxycarbonyl, carboxy, hydroxyalkyl, alkanesulfonyl, arenesulfonyl, alkanesulfonamido, arenesulfonamido, aralkylsulfonamido, alkylcarbonyl, acyloxy, cyano, and ureido groups.

The term "halogen" or "halo" as employed herein refers to chlorine, 15 bromine, fluorine, or iodine.

As herein employed, the term "acyl" refers to an alkylcarbonyl or arylcarbonyl substituent.

The term "acylamino" refers to an amide group attached at the nitrogen atom. The term "carbamoyl" refers to an amide group attached at the carbonyl 20 carbon atom. The nitrogen atom of an acylamino or carbamoyl substituent may be additionally substituted. The term "sulfonamido" refers to a sulfonamide substituent attached by either the sulfur or the nitrogen atom. The term "amino" is meant to include  $\text{NH}_2$ , alkylamino, arylamino, and cyclic amino groups.

The term "ureido" as employed herein refers to a substituted or 25 unsubstituted urea moiety.

### Compounds

In a first aspect, the invention provides novel inhibitors of histone deacetylase. In a first embodiment, the novel inhibitors of histone deacetylase 30 are represented by formula (1):



wherein

5 Cy is cycloalkyl, aryl, heteroaryl, or heterocyclyl, any of which may be optionally substituted;

L' is  $-(CH_2)_m-W-$ , where m is 0, 1, 2, 3, or 4, and W is selected from the group consisting of  $-C(O)NH-$ ,  $-S(O)_2NH-$ ,  $-NHC(O)-$ ,  $-NHS(O)_2-$ , and  $-NH-C(O)-NH-$ ;

10 Ar is arylene, wherein said arylene optionally may be additionally substituted and optionally may be fused to an aryl or heteroaryl ring, or to a saturated or partially unsaturated cycloalkyl or heterocyclic ring, any of which may be optionally substituted;

Y<sup>1</sup> is a chemical bond or a straight- or branched-chain saturated alkylene,  
15 wherein said alkylene may be optionally substituted; and

Z is selected from the group consisting of aniliny, pyridyl, thiadiazolyl, and  $-O-M$ , M being H or a pharmaceutically acceptable cation;

provided that when L' is  $-C(O)NH-$ , Y is  $-(CH_2)_n-$ , n being 1, 2, or 3, and Z is  $-O-M$ , then Cy is not aminophenyl, dimethylaminophenyl, or hydroxyphenyl;  
20 and further provided that when L' is  $-C(O)NH-$  and Z is pyridyl, then Cy is not substituted indoliny.

In certain preferred embodiments, Cy is  $C_6-C_{10}$  aryl, more preferably  $C_6-C_{10}$  aryl, and most preferably phenyl or naphthyl, any of which may be optionally substituted.  
25 In certain other preferred embodiments, Cy is heteroaryl. In some preferred embodiments, the heteroaryl group is selected from the group consisting of thienyl, benzothienyl, furyl, benzofuryl, quinolyl, isoquinolyl, and thiazolyl, any of which may be optionally substituted. In certain particularly preferred embodiments, Cy is selected from the group consisting of phenyl, naphthyl, thienyl, benzothienyl, and quinolyl, any of which may be optionally substituted.  
30

L' is  $-(CH_2)_m-W-$ , where m is 0, 1, 2, 3, or 4, and W is selected from the group consisting of  $-C(O)NH-$ ,  $-S(O)_2NH-$ ,  $-NHC(O)-$ ,  $-NHS(O)_2-$ , and  $-NH-C(O)-NH-$ . Preferably, m is 0, 1, or 2, more preferably 0 or 1.

5 Preferably, Ar is  $C_6-C_{10}$  arylene, more preferably  $C_6-C_{10}$  arylene, any of which may be additionally substituted. In certain preferred embodiments, Ar is phenylene, preferably 4-phenylene. In some preferred embodiments, the phenylene is fused to an aryl or heteroaryl ring, or to a saturated or partially unsaturated cycloalkyl or heterocyclic ring, any of which groups also may be  
 10 optionally substituted.

$Y^1$  is a chemical bond or is a straight- or branched-chain alkylene, which may be optionally substituted. In some preferred embodiments,  $Y^1$  is a chemical bond, and the group  $-C(O)NH-Z$  is directly attached to Ar. In some other preferred embodiments,  $Y^1$  is alkylene, preferably saturated alkylene.  
 15 Preferably, the saturated alkylene is  $C_1-C_6$  alkylene, more preferably  $C_1-C_4$  alkylene, still more preferably  $C_1-C_3$  alkylene, and yet still more preferably  $C_1-C_2$  alkylene, any of which may be optionally substituted. In some particularly preferred embodiments,  $Y^1$  is methylene.

Substituted alkyl, aryl, heterocyclyl, or heteroaryl groups have one or  
 20 more; preferably between one and about three, more preferably one or two substituents, which are preferably selected from the group consisting of  $C_1-C_6$  alkyl, preferably  $C_1-C_4$  alkyl; halo, preferably Cl, Br, or F; haloalkyl, preferably (halo)<sub>1-3</sub>( $C_1-C_6$ )alkyl, more preferably (halo)<sub>1-3</sub>( $C_1-C_3$ )alkyl, and most preferably  $CF_3$ ;  $C_1-C_6$  alkoxy, preferably methoxy, ethoxy, or benzyloxy;  $C_6-C_{10}$  aryloxy, preferably phenoxy;  $C_1-C_6$  alkoxycarbonyl, preferably  $C_1-C_3$  alkoxycarbonyl, most preferably carbomethoxy or carboethoxy;  $C_6-C_{10}$  aryl, preferably phenyl; ( $C_6-C_{10}$ )ar( $C_1-C_6$ )alkyl, preferably ( $C_6-C_{10}$ )ar( $C_1-C_3$ )alkyl, more preferably benzyl, naphthylmethyl or phenethyl; hydroxy( $C_1-C_6$ )alkyl, preferably hydroxy( $C_1-C_3$ )alkyl, more preferably hydroxymethyl; amino( $C_1-C_6$ )alkyl, preferably  
 25 amino( $C_1-C_3$ )alkyl, more preferably aminomethyl; ( $C_1-C_6$ )alkylamino, preferably methylamino, ethylamino, or propylamino; di-( $C_1-C_6$ )alkylamino, preferably dimethylamino or diethylamino; ( $C_1-C_6$ )alkylcarbamoyl, preferably methylcarbamoyl, dimethylcarbamoyl, or benzylcarbamoyl; ( $C_6-C_{10}$ )-arylcarbamoyl, preferably phenylcarbamoyl; ( $C_1-C_6$ )alkaneacylamino, preferably  
 30

5 acetylamino; (C<sub>6</sub>-C<sub>10</sub>)areneacylamino, preferably benzoylamino; (C<sub>1</sub>-C<sub>6</sub>)alkanesulfonyl, preferably methanesulfonyl; (C<sub>1</sub>-C<sub>6</sub>)alkanesulfonamido, preferably methanesulfonamido; (C<sub>6</sub>-C<sub>10</sub>)arenesulfonyl, preferably benzenesulfonyl or toluenesulfonyl; (C<sub>6</sub>-C<sub>10</sub>)arenesulfonamido, preferably benzenesulfonyl or toluenesulfonyl; (C<sub>6</sub>-C<sub>10</sub>)ar(C<sub>1</sub>-C<sub>6</sub>)alkylsulfonamido, preferably  
 10 benzylsulfonamido; C<sub>1</sub>-C<sub>6</sub> alkylcarbonyl, preferably C<sub>1</sub>-C<sub>3</sub> alkylcarbonyl, more preferably acetyl; (C<sub>1</sub>-C<sub>6</sub>)acyloxy, preferably acetoxy; cyano; amino; carboxy; hydroxy; ureido; and nitro. One or more carbon atoms of an alkyl, cycloalkyl, or heterocyclyl group may also be optionally substituted with an oxo group.

In some particularly preferred embodiments, Cy is a phenyl, naphthyl,  
 15 thienyl, benzothienyl, or quinolyl moiety which is unsubstituted or is substituted by one or two substituents independently selected from the group consisting of C<sub>1</sub>-C<sub>6</sub> alkyl, C<sub>1</sub>-C<sub>6</sub> haloalkyl, C<sub>6</sub>-C<sub>10</sub> aryl, (C<sub>6</sub>-C<sub>10</sub>)ar(C<sub>1</sub>-C<sub>6</sub>)alkyl, halo, nitro, hydroxy, C<sub>1</sub>-C<sub>6</sub> alkoxy, C<sub>1</sub>-C<sub>6</sub> alkoxycarbonyl, carboxy, and amino.

In some preferred embodiments, Z is anilinyll or pyridyl, preferably  
 20 2-anilinyll or 2-pyridyl. In some other preferred embodiments, Z is thiadiazolyl, preferably 1,3,4-thiadiazol-2-yl, and more preferably a 5-substituted-1,3,4-thiadiazol-2-yl. The thiadiazolyl is preferably substituted with a substituent selected from the group consisting of thiol, trifluoromethyl, amino, and  
 sulfonamido.

25 In still other preferred embodiments, Z is -O-M, wherein M is hydrogen or any pharmaceutically acceptable cation. Examples of pharmaceutically acceptable cations include, without limitation, sodium, potassium, magnesium, and calcium.

30 In a second embodiment, the invention provides novel inhibitors of histone deacetylase represented by formula (2):



wherein

5 Cy is cycloalkyl, aryl, heteroaryl, or heterocyclyl, any of which may be optionally substituted, provided that Cy is not a (spirocycloalkyl)heterocyclyl;

L<sup>2</sup> is C<sub>1</sub>-C<sub>6</sub> saturated alkylene or C<sub>2</sub>-C<sub>6</sub> alkenylene, wherein the alkylene or alkenylene optionally may be substituted, provided that L<sup>2</sup> is not -C(O)-, and wherein one of the carbon atoms of the alkylene optionally may be replaced by a  
10 heteroatom moiety selected from the group consisting of O; NR', R' being alkyl, acyl, or hydrogen; S; S(O); or S(O)<sub>2</sub>;

Ar is arylene, wherein said arylene optionally may be additionally substituted and optionally may be fused to an aryl or heteroaryl ring, or to a saturated or partially unsaturated cycloalkyl or heterocyclic ring, any of which  
15 may be optionally substituted; and

Y<sup>2</sup> is a chemical bond or a straight- or branched-chain saturated alkylene, which may be optionally substituted, provided that the alkylene is not substituted with a substituent of the formula -C(O)R wherein R comprises an α-amino acyl moiety; and

20 Z is selected from the group consisting of aniliny, pyridyl, thiadiazolyl, and -O-M, M being H or a pharmaceutically acceptable cation;

provided that when the carbon atom to which Cy is attached is oxo substituted, then Cy and Z are not both pyridyl.

25 Preferred substituents Cy, Ar, and Z according to this aspect of the invention are as defined above for the first embodiment. Preferred substituents Y<sup>2</sup> are as defined above for Y<sup>1</sup>. In some preferred embodiments, L<sup>2</sup> is saturated C<sub>1</sub>-C<sub>6</sub> alkylene, more preferably C<sub>1</sub>-C<sub>4</sub> alkylene, still more preferably C<sub>1</sub>-C<sub>4</sub> alkylene, any of which groups may be optionally substituted. In some other  
30 preferred embodiments, L<sup>2</sup> is C<sub>2</sub>-C<sub>6</sub> alkenylene, more preferably C<sub>2</sub>-C<sub>4</sub> alkenylene, and still more preferably C<sub>2</sub>-C<sub>4</sub> alkenylene, any of which groups may be optionally substituted. The alkylene or alkenylene group may be substituted at one or more carbon positions with a substituent preferably selected from the list of preferred substituents recited above. More preferably, L<sup>2</sup> is substituted at one

5 or two positions with a substituent independently selected from the group consisting of  $C_1$ - $C_6$  alkyl,  $C_6$ - $C_{10}$  aryl, amino, oxo, hydroxy,  $C_1$ - $C_6$  alkoxy, and  $C_6$ - $C_{10}$  aryloxy. In some particularly preferred embodiments, the alkylene or alkenylene group is substituted with one or two oxo or hydroxy groups. However,  $L^2$  preferably is not  $-C(O)-$ , and when the carbon atom to which Cy is  
 10 attached is oxo substituted; Cy and Z preferably are not both pyridyl.

In some preferred embodiments,  $L^1$  is  $C_1$ - $C_6$  saturated alkylene, wherein one of the carbon atoms of the saturated alkylene is replaced by a heteroatom moiety selected from the group consisting of O;  $NR'$ ,  $R'$  being alkyl, acyl, or hydrogen; S;  $S(O)$ ; or  $S(O)_2$ . Preferably, the carbon atom adjacent to Cy is  
 15 replaced by a heteroatom moiety. In some particularly preferred embodiments,  $L^1$  is selected from the group consisting of  $-S-(CH_2)_2-$ ,  $-S(O)-(CH_2)_2-$ ,  $-S(O)_2-(CH_2)_2-$ ,  $-S-(CH_2)_3-$ ,  $-S(O)-(CH_2)_3-$ , and  $-S(O)_2-(CH_2)_3-$ .

In a third embodiment, the invention provides novel inhibitors of histone  
 20 deacetylase represented by formula (3):



wherein

Cy is cycloalkyl, aryl, heteroaryl, or heterocyclcyl, any of which may be optionally substituted, provided that Cy is not a (spirocycloalkyl)heterocyclcyl;

25  $L^3$  is selected from the group consisting of

(a)  $-(CH_2)_m-W-$ , where m is 0, 1, 2, 3, or 4, and W is selected from the group consisting of  $-C(O)NH-$ ,  $-S(O)_2NH-$ ,  $-NHC(O)-$ ,  $-NHS(O)_2-$ , and  $-NH-C(O)-NH-$ ; and

(b)  $C_1$ - $C_6$  alkylene or  $C_2$ - $C_6$  alkenylene, wherein the alkylene or  
 30 alkenylene optionally may be substituted, provided that  $L^3$  is not  $-C(O)-$ , and wherein one of the carbon atoms of the alkylene optionally may be replaced by O;  $NR'$ ,  $R'$  being alkyl, acyl, or hydrogen; S;  $S(O)$ ; or  $S(O)_2$ ;

Ar is arylene, wherein said arylene optionally may be additionally substituted and optionally may be fused to an aryl or heteroaryl ring, or to a

5 saturated or partially unsaturated cycloalkyl or heterocyclic ring, any of which may be optionally substituted; and

$Y^3$  is  $C_2$  alkenylene or  $C_2$  alkynylene, wherein one or both carbon atoms of the alkenylene optionally may be substituted with alkyl, aryl, alkaryl, or aralkyl; and

10 Z is selected from the group consisting of aniliny, pyridyl, thiadiazolyl, and -O-M, M being H or a pharmaceutically acceptable cation;

provided that when Cy is unsubstituted phenyl, Ar is not phenyl wherein  $L^3$  and  $Y^3$  are oriented *ortho* or *meta* to each other.

15 Preferred substituents Cy, Ar, and Z according to this aspect of the invention are as defined above for the first embodiment. Preferred substituents  $L^3$  are as defined above for  $L^1$  or  $L^2$ .

Preferably,  $Y^3$  is  $C_2$  alkenylene or  $C_2$  alkynylene, wherein one or both carbon atoms of the alkenylene optionally may be substituted with  $C_1$ - $C_6$  alkyl,  $C_6$ - $C_{10}$  aryl,  $(C_1-C_6)alk(C_6-C_{10})aryl$ , or  $(C_6-C_{10})ar(C_1-C_6)alkyl$ . More preferably,  $Y^3$  is  $C_2$  alkenylene or  $C_2$  alkynylene, wherein one or both carbon atoms of the alkenylene optionally may be substituted with  $C_1$ - $C_4$  alkyl,  $C_6$ - $C_{10}$  aryl,  $(C_1-C_4)alk(C_6-C_{10})aryl$ , or  $(C_6-C_{10})ar(C_1-C_4)alkyl$ . Still more preferably,  $Y^3$  is selected from the group consisting of  $-C\equiv C-$ ,  $-CH=CH-$ ,  $-C(CH_3)=CH-$ , and  $-CH=C(CH_3)-$ .

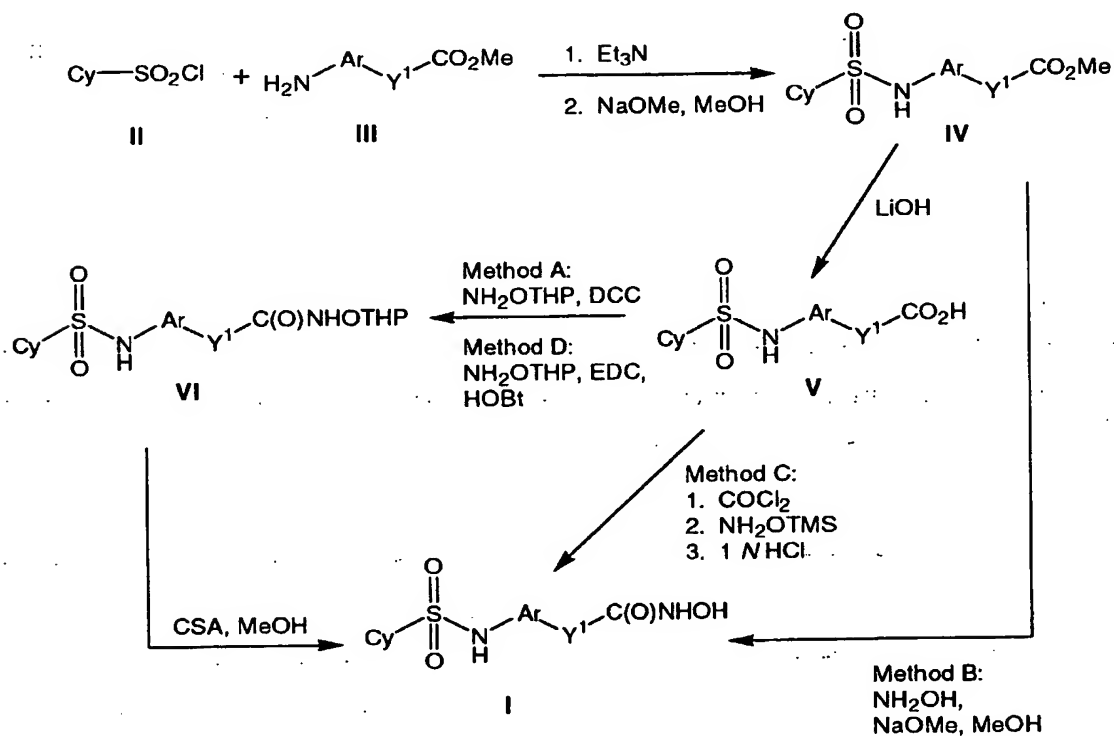
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### Synthesis

Compounds of formula  $Cy-L^1-Ar-Y^1-C(O)-NH-O-M$ , wherein  $L^1$  is  $-S(O)_2NH-$ , preferably may be prepared according to the synthetic routes depicted in Schemes 1-3. Accordingly, in certain preferred embodiments, compounds I are preferably prepared according to the general synthetic route depicted in Scheme 1. Thus, a sulfonyl chloride (II) is treated with an amine (III) in a solvent such as methylene chloride in the presence of an organic base such as triethylamine. Treatment of the crude product with a base such as sodium methoxide in an alcoholic solvent such as methanol effects cleavage of any

- 5 dialkylated material and affords the sulfonamide (IV). Hydrolysis of the ester function in IV can be effected by treatment with a hydroxide base, such as lithium hydroxide, in a solvent mixture such as tetrahydrofuran and methanol to afford the corresponding acid (V).

Scheme 1



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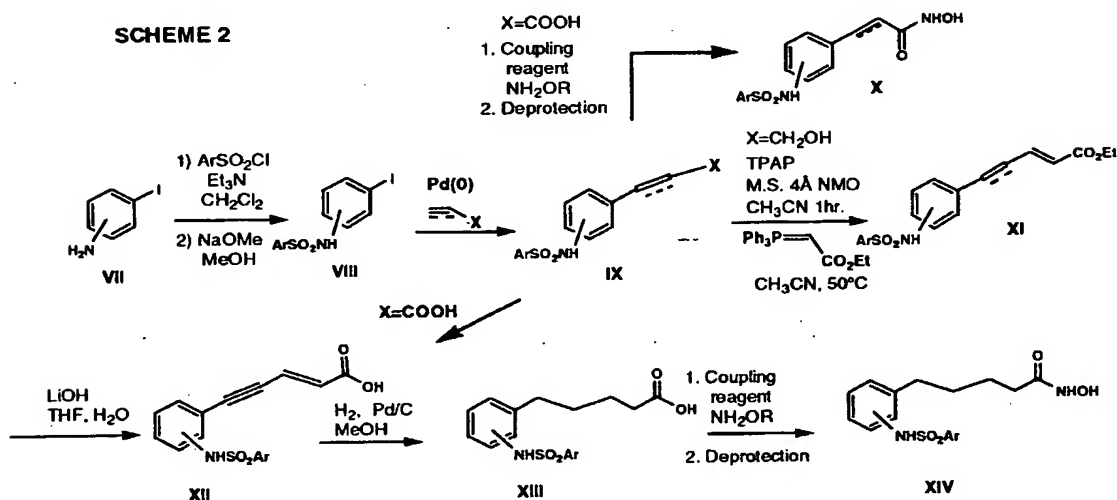
- In some embodiments, conversion of the acid V to the hydroxamic acid I may be accomplished by coupling V with a protected hydroxylamine, such as tetrahydropyranyloxyamine ( $\text{NH}_2\text{OTHP}$ ), to afford the protected hydroxamate VI, followed by acidic hydrolysis of VI to provide the hydroxamic acid I. The coupling reaction is preferably accomplished with the coupling reagent dicyclohexylcarbodiimide (DCC) in a solvent such as methylene chloride (Method A) or with the coupling reagent 1-(3-dimethylaminopropyl)-3-ethylcarbodiimide in presence of *N*-hydroxy benzotriazole in an aprotic solvent



5 such as dimethylformamide (Method D). Other coupling reagents are known in the art and may also be used for this reaction. Hydrolysis of VI is preferably effected by treatment with an organic acid such as camphorsulfonic acid in a protic solvent such as methanol.

Alternatively, in some other embodiments, acid V is converted to the  
10 corresponding acid chloride, preferably by treatment with oxalic chloride, followed by the addition of a protected hydroxylamine such as *O*-trimethylsilylhydroxylamine in a solvent such as methylene chloride, which then provides the hydroxylamine I upon workup (Method C).

In still other embodiments, the ester IV is preferably treated with  
15 hydroxylamine in a solvent such as methanol in the presence of a base such as sodium methoxide to furnish the hydroxylamine I directly (Method B).



20 Compounds of formula X and XIV preferably are prepared according to the general procedure outlined in Scheme 2. Thus, an aminoaryl halide (VII) is treated with a sulfonyl chloride in presence of a base such as triethylamine, followed by treatment with an alkoxide base, to furnish the sulfonamide VIII. One of skill in the art will recognize that reverse sulfonamide analogs can be  
25 readily prepared by an analogous procedure, treating a haloarenesulfonyl halide with an arylamine.

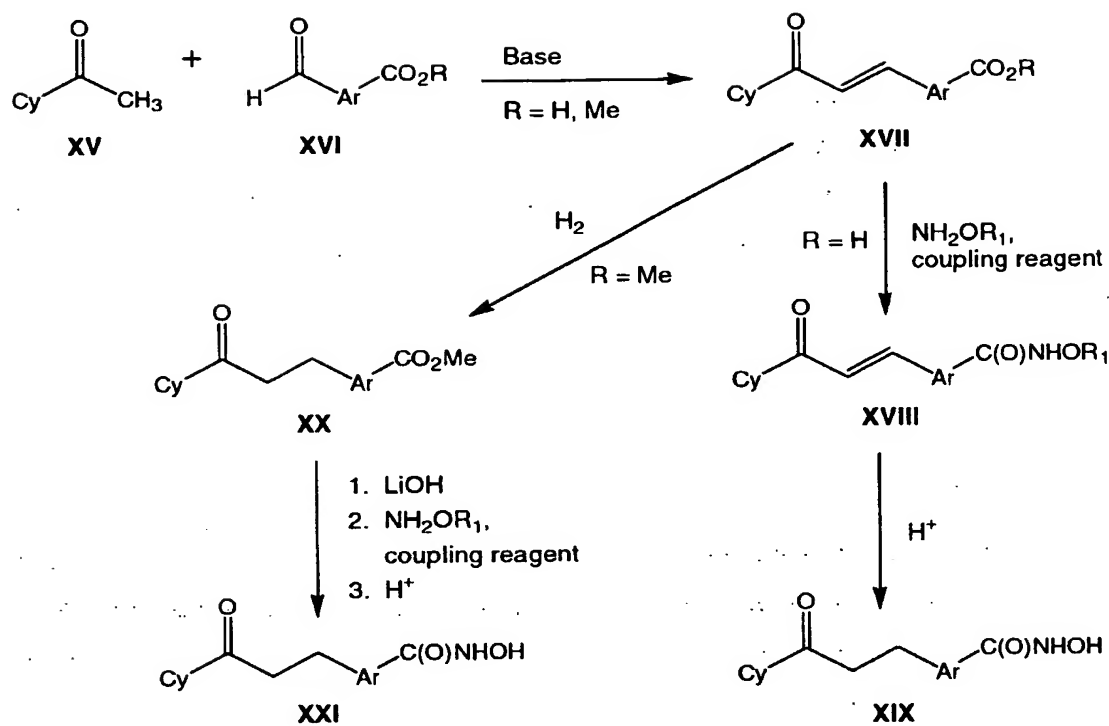
5           Compound VIII is coupled with a terminal acetylene or olefinic compound in the presence of a palladium catalyst such as tetrakis(triphenylphosphine)palladium(0) in a solvent such as pyrrolidine to afford IX.

          Oxidation of the compound of formula IX ( $X=CH_2OH$ ), followed by  
10   homologation of the resulting aldehyde using a Wittig type reagent such as carbethoxymethylenetriphenylphosphorane in a solvent such as acetonitrile, gives the compound of formula XI. Basic hydrolysis of XI, such as by treatment with lithium hydroxide in a mixture of THF and water, provides the acid XII. Hydrogenation of XII may preferably be performed over a palladium catalyst  
15   such as Pd/C in a protic solvent such as methanol to afford the saturated acid XIII. Coupling of the acid XIII with an *O*-protected hydroxylamine such as *O*-tetrahydropyranylhdroxylamine is effected by treatment with a coupling reagent such as 1-(3-dimethylaminopropyl)-3-ethylcarbodiimide in the presence of *N*-hydroxybenzotriazole (HOBT), or *N,N*-dicyclohexylcarbodiimide (DCC), in  
20   a solvent such as DMF, followed by deprotection to furnish the compound of general formula XIV.

          The acid IX, wherein  $X=COOH$ , may be coupled directly with an *O*-protected hydroxylamine such as *O*-tetrahydropyranylhdroxylamine, followed by deprotection of the hydroxy protecting group to furnish the  
25   hydroxamic acid X.

          Compounds of formula  $Cy-L^1-Ar-Y^1-C(O)-NH-O-M$ , wherein  $L^1$  is  $-C(O)NH-$ , preferably may be prepared according to the synthetic routes analogous to those depicted in Schemes 1-2, substituting acid chloride starting materials for the sulfonyl chloride starting materials in those Schemes.

## Scheme 3



5

Compounds of the formula  $Cy-L^2-Ar-Y^2-C(O)-NH-O-M$  are preferably prepared according to the synthetic routes outlined in Schemes 3-5.

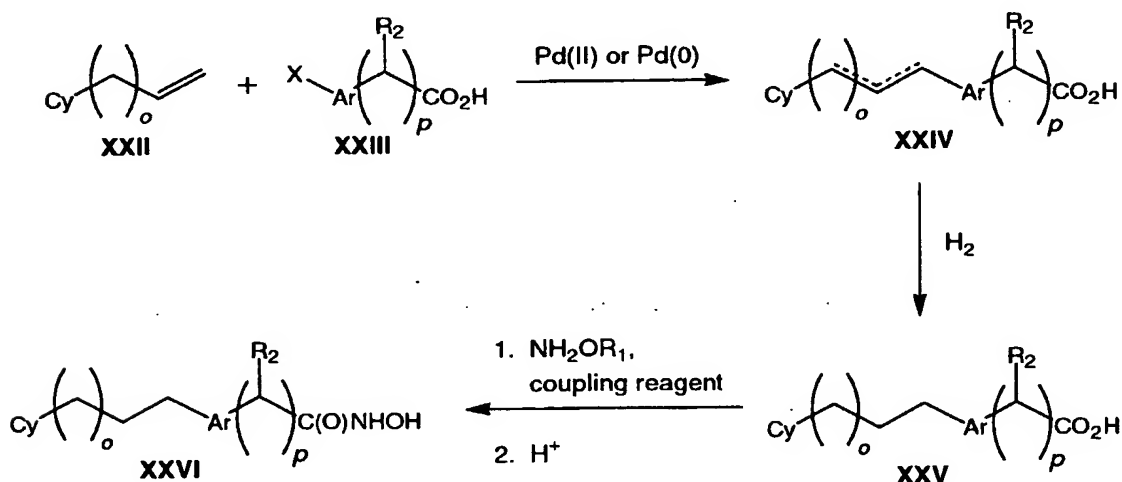
Accordingly, in certain preferred embodiments, compounds of formulae XIX and XXI ( $L^2 = -C(O)-CH=CH-$  or  $-C(O)-CH_2CH_2-$ ) preferably are prepared according to the route described in Scheme 3. Thus, a substituted aryl acetophenone (XV) is treated with an aryl aldehyde (XVI) in a protic solvent such as methanol in the presence of a base such as sodium methoxide to afford the enone XVII.

The acid substituent of XVII ( $R = H$ ) is coupled with an  $O$ -protected hydroxylamine such as  $O$ -tetrahydropyranylhydroxylamine ( $R_1 =$  tetrahydropyranyl) to afford the  $O$ -protected- $N$ -hydroxybenzamide XVIII. The coupling reaction is preferably performed by treating the acid and

- 5 hydroxylamine with dicyclohexylcarbodiimide in a solvent such as methylene chloride or with 1-(3-dimethylaminopropyl)-3-ethylcarbodiimide in the presence of *N*-hydroxybenzotriazole in a solvent such as dimethylformamide. Other coupling reagents are known in the art and may also be used in this reaction. *O*-Deprotection is accomplished by treatment of XVIII with an acid such as camphorsulfonic acid in a solvent such as methanol to afford the hydroxamic acid XIX ( $L^2 = -C(O)-CH=CH-$ ).
- 10 acid XIX ( $L^2 = -C(O)-CH=CH-$ ).

- Saturated compounds of formula XXI ( $L^2 = -C(O)-CH_2CH_2-$ ) are preferably prepared by hydrogenation of XVII ( $R = Me$ ) over a palladium catalyst, such as 10% Pd/C, in a solvent such as methanol-tetrahydrofuran.
- 15 Basic hydrolysis of the resultant product XIX with lithium hydroxide, followed by *N*-hydroxy amide formation and acid hydrolysis as described above, then affords the hydroxamic acid XXI.

Scheme 4

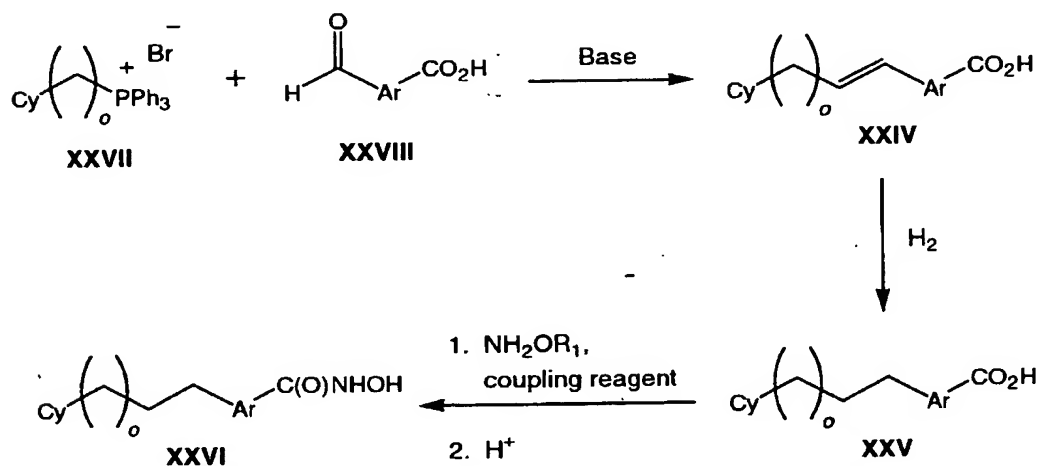


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Compounds of formula XXVI ( $L^2 = -(CH_2)_{n-2}-$ ) are preferably prepared by the general procedures described in Schemes 4 and 5. Thus, in some

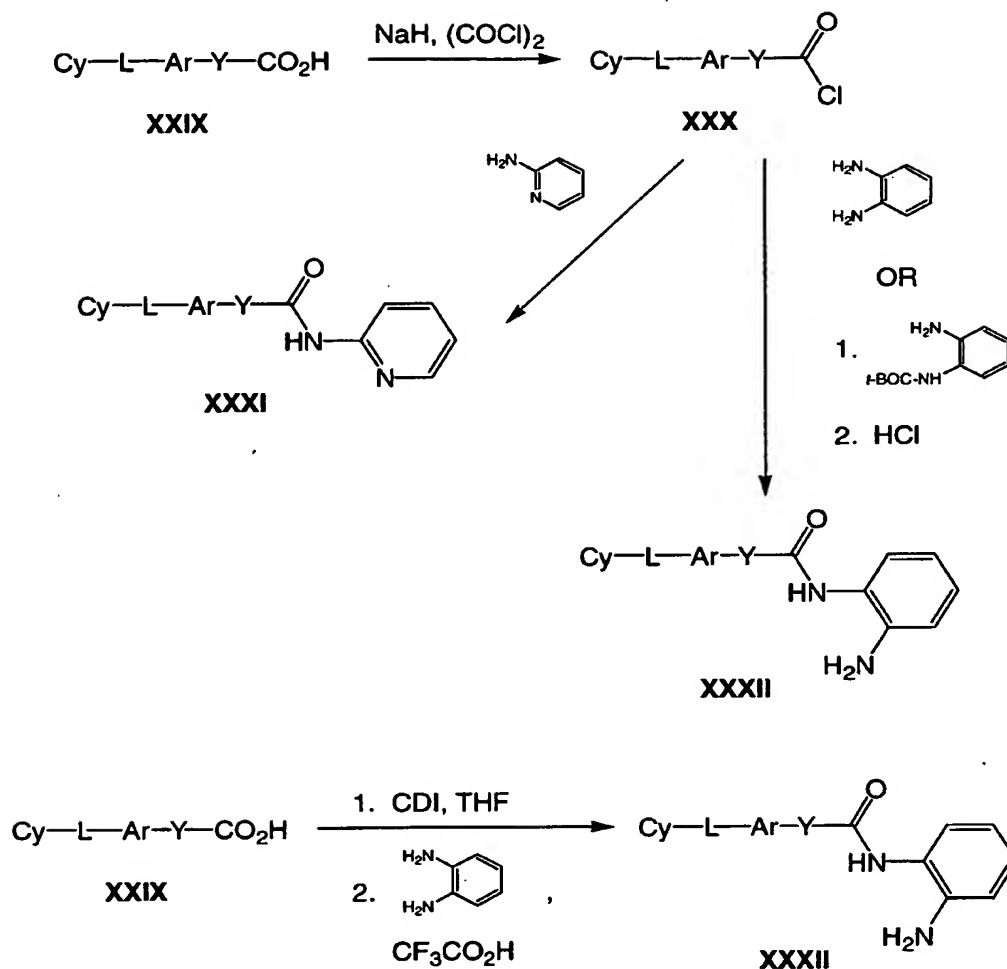
- 5 embodiments, a terminal olefin (XXII) is coupled with an aryl halide (XXIII) in the presence of a catalytic amount of a palladium source, such as palladium acetate or tris(dibenzylideneacetone)dipalladium(0), a phosphine, such as triphenylphosphine; and a base, such as triethylamine, in a solvent such as acetonitrile to afford the coupled product XXIV. Hydrogenation, followed by
- 10 *N*-hydroxyamide formation and acid hydrolysis, as described above, affords the hydroxamic acid XXVI.

## Scheme 5



- 15 Alternatively, in some other embodiments, a phosphonium salt of formula XXVII is treated with an aryl aldehyde of formula XXVIII in the presence of base, such as lithium hexamethyldisilazide, in a solvent, such as tetrahydrofuran, to produce the compound XXIV. Hydrogenation, followed by
- N*-hydroxyamide formation and acidic hydrolysis, then affords the compounds
- 20 XXVI.

## Scheme 6



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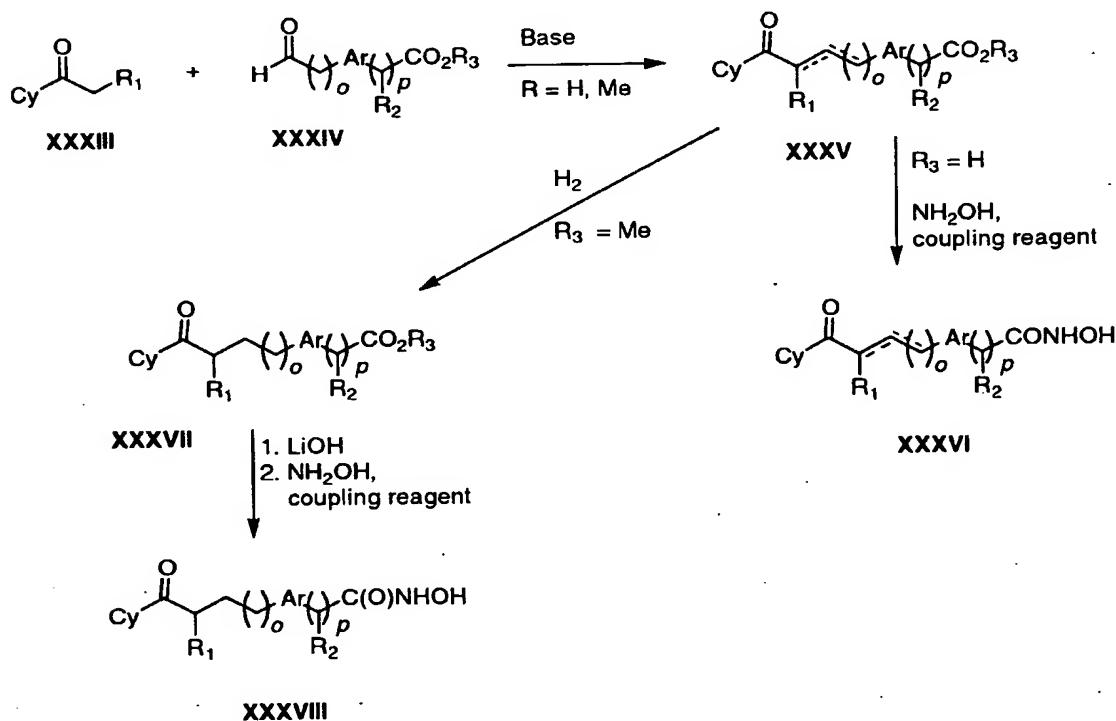
Compounds of formula  $\text{Cy-L-Ar-Y-C(O)-NH-Z}$ , wherein L is  $\text{L}^1$  or  $\text{L}^2$ , Y is  $\text{Y}^1$  or  $\text{Y}^2$ , and Z is anilinylyl or pyridyl, are preferably prepared according to synthetic routes outlined in Scheme 6. An acid of formula  $\text{Cy-L-Ar-Y-C(O)-OH}$  (XXIX), prepared by one of the methods shown in Schemes 1-5, is converted to the corresponding acid chloride XXX according to standard methods, e.g., by treatment with sodium hydride and oxalyl chloride. Treatment of XXX with 2-aminopyridine and a tertiary base such as *N*-methylmorpholine, preferably in dichloromethane at reduced temperature, then affords the pyridyl amide XXXI.

10

- 5 In a similar fashion, the acid chloride XXX may be treated with 1,2-phenylenediamine to afford the anilinyll amide XXXII. Alternatively, the acid chloride XXX may be treated with a mono-protected 1,2-phenylenediamine, such as 2-(*t*-BOC-amino)aniline, followed by deprotection, to afford XXXII.

- 10 In another alternative procedure, the acid XXIX may be activated by treatment with carbonyldiimidazole (CDI), followed by treatment with 1,2-phenylenediamine and trifluoroacetic acid to afford the anilinyll amide XXXII.

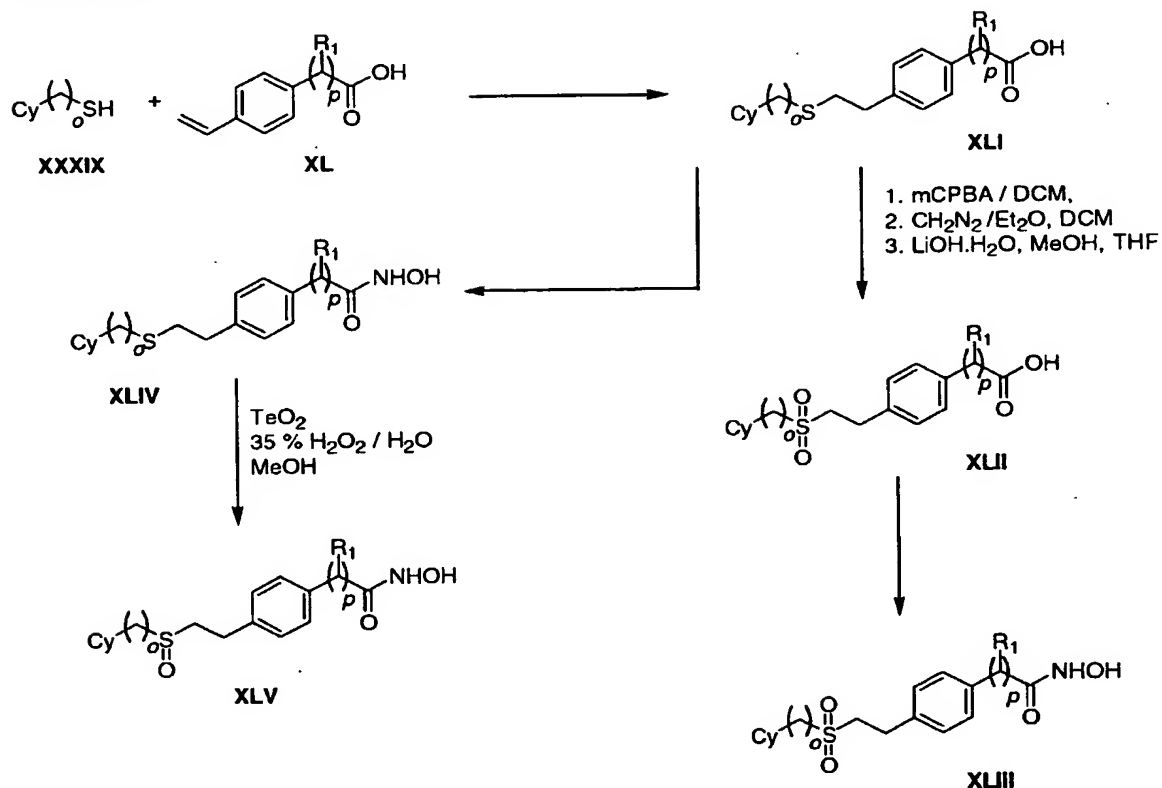
Scheme 7



- 15 Compounds of formula XXXVIII (L<sup>2</sup> = -C(O)-alkylene-) preferably are prepared according to the general procedure depicted in Scheme 7. Thus, Aldol condensation of ketone XXXIII (R<sub>1</sub> = H or alkyl) with aldehyde XXXIV affords the adduct XXXV. The adduct XXXV may be directly converted to the corresponding hydroxamic acid XXXVI, or may first undergo hydrogenation to

- 5 afford the saturated compound XXVII and then be converted to the hydroxamic acid XXXVIII.

Scheme 8



10

- Compounds of formula (2), wherein one of the carbon atoms in  $\text{L}^2$  is replaced with S, S(O), or S(O)<sub>2</sub> preferably are prepared according to the general procedure outlined in Scheme 8. Thus, thiol XXXIX is added to olefin XL to produce XLI. The reaction is preferably conducted in the presence of a radical
- 15 initiator such as 2,2'-azobisisobutyronitrile (AIBN) or 1,1'-azobis(cyclohexanecarbonitrile) (VAZO™). Sulfide oxidation, preferably by treatment with *m*-chloroperbenzoic acid (mCPBA), affords the corresponding sulfone, which is conveniently isolated after conversion to the methyl ester by



5 treatment with diazomethane. Ester hydrolysis then affords the acid XLII, which is converted to the hydroxamic acid XLIII according to any of the procedures described above. The sulfide XLI also may be converted directly to the corresponding hydroxamic acid XLIV, which then may be selectively oxidized to the sulfoxide XLV, for example, by treatment with hydrogen  
10 peroxide and tellurium dioxide.

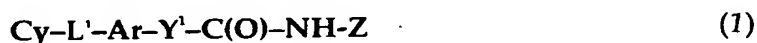
### Pharmaceutical Compositions

In a second aspect, the invention provides pharmaceutical compositions comprising an inhibitor of histone deacetylase represented by any one of  
15 formulae (1)-(6) and a pharmaceutically acceptable carrier, excipient, or diluent. Compounds of the invention may be formulated by any method well known in the art and may be prepared for administration by any route, including, without limitation, parenteral, oral, sublingual, transdermal, topical, intranasal, intratracheal, or intrarectal. In certain preferred embodiments, compounds of  
20 the invention are administered intravenously in a hospital setting. In certain other preferred embodiments, administration may preferably be by the oral route.

The characteristics of the carrier will depend on the route of administration. As used herein, the term "pharmaceutically acceptable" means a  
25 non-toxic material that is compatible with a biological system such as a cell, cell culture, tissue, or organism, and that does not interfere with the effectiveness of the biological activity of the active ingredient(s). Thus, compositions according to the invention may contain, in addition to the inhibitor, diluents, fillers, salts, buffers, stabilizers, solubilizers, and other materials well known in the art. The  
30 preparation of pharmaceutically acceptable formulations is described in, *e.g.*, *Remington's Pharmaceutical Sciences*, 18th Edition, ed. A. Gennaro, Mack Publishing Co., Easton, PA, 1990.

## 5 Inhibition of Histone Deacetylase

In a third aspect, the invention provides a method of inhibiting histone deacetylase in a cell, comprising contacting a cell in which inhibition of histone deacetylase is desired with an inhibitor of histone deacetylase according to the invention. In a first embodiment according to this aspect of the invention, the  
 10 inhibitor of histone deacetylase is represented by the formula (1)



wherein

Cy is cycloalkyl, aryl, heteroaryl, or heterocyclyl, any of which may be optionally substituted;

15 L<sup>1</sup> is  $-(\text{CH}_2)_m\text{-W-}$ , where m is 0, 1, 2, 3, or 4, and W is selected from the group consisting of  $-\text{C(O)NH-}$ ,  $-\text{S(O)}_2\text{NH-}$ ,  $-\text{NHC(O)-}$ ,  $-\text{NHS(O)}_2\text{-}$ , and  $-\text{NH-C(O)-NH-}$ ;

Ar is arylene, wherein said arylene optionally may be additionally substituted and optionally may be fused to an aryl or heteroaryl ring, or to a  
 20 saturated or partially unsaturated cycloalkyl or heterocyclic ring, any of which may be optionally substituted;

Y<sup>1</sup> is a chemical bond or a straight- or branched-chain saturated alkylene, wherein said alkylene may be optionally substituted; and

Z is selected from the group consisting of aniliny, pyridyl, 2-thioxo-1,3,4-  
 25 thiadiazol-2-yl, and  $-\text{O-M}$ , M being H or a pharmaceutically acceptable cation;

provided that when L<sup>1</sup> is  $-\text{C(O)NH-}$ , Y is  $-(\text{CH}_2)_n\text{-}$ , n being 1, 2, or 3, and Z is  $-\text{O-M}$ , then Cy is not aminophenyl, dimethylaminophenyl, or hydroxyphenyl.

In a second embodiment according to this aspect of the invention, the  
 30 inhibitor of histone deacetylase is represented by formula (2):



wherein

5 Cy is cycloalkyl, aryl, heteroaryl, or heterocyclyl, any of which may be optionally substituted;

L<sup>1</sup> is C<sub>1</sub>-C<sub>6</sub> saturated alkylene or C<sub>2</sub>-C<sub>6</sub> alkenylene, either of which may be optionally substituted;

10 Ar is arylene, wherein said arylene optionally may be additionally substituted and optionally may be fused to an aryl or heteroaryl ring, or to a saturated or partially unsaturated cycloalkyl or heterocyclic ring, any of which may be optionally substituted; and

Y<sup>2</sup> is a chemical bond or a straight- or branched-chain saturated alkylene, which may be optionally substituted, provided that the alkylene is not  
15 substituted with a substituent of the formula -C(O)R wherein R comprises an  $\alpha$ -amino acyl moiety; and

Z is selected from the group consisting of aniliny, pyridyl, 2-thioxo-1,3,4-thiadiazol-2-yl, and -O-M, M being H or a pharmaceutically acceptable cation.

20 In a third embodiment according to this aspect of the invention, the inhibitor of histone deacetylase is represented by the formula (3):



wherein

25 Cy is cycloalkyl, aryl, heteroaryl, or heterocyclyl, any of which may be optionally substituted, provided that Cy is not a (spirocycloalkyl)heterocyclyl;

L<sup>1</sup> is selected from the group consisting of

(a) -(CH<sub>2</sub>)<sub>m</sub>-W-, where m is 0, 1, 2, 3, or 4, and W is selected from the group consisting of -C(O)NH-, -S(O)<sub>2</sub>NH-, -NHC(O)-, -NHS(O)<sub>2</sub>-, and -NH-C(O)-NH-; and

30 (b) C<sub>1</sub>-C<sub>6</sub> alkylene or C<sub>2</sub>-C<sub>6</sub> alkenylene, wherein the alkylene or alkenylene optionally may be substituted, provided that L<sup>1</sup> is not -C(O)-, and wherein one of the carbon atoms of the alkylene optionally may be replaced by O; NR', R' being alkyl, acyl, or hydrogen; S; S(O); or S(O)<sub>2</sub>;

5 Ar is arylene, wherein said arylene optionally may be additionally substituted and optionally may be fused to an aryl or heteroaryl ring, or to a saturated or partially unsaturated cycloalkyl or heterocyclic ring, any of which may be optionally substituted; and

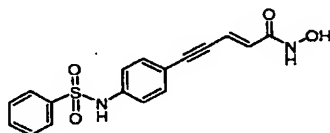
Y<sup>3</sup> is C<sub>2</sub> alkenylene or C<sub>2</sub> alkynylene, wherein one or both carbon atoms of  
10 the alkenylene optionally may be substituted with alkyl, aryl, alkaryl, or aralkyl; and

Z is selected from the group consisting of anilinyll, pyridyl, thiadiazolyl, and -O-M, M being H or a pharmaceutically acceptable cation;

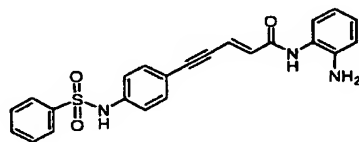
provided that when Cy is unsubstituted phenyl, Ar is not phenyl wherein  
15 L<sup>3</sup> and Y<sup>3</sup> are oriented *ortho* or *meta* to each other.

In a fourth embodiment according to this aspect of the invention, the novel histone deacetylase inhibitor is selected from the group represented by formulae (4)-(6):

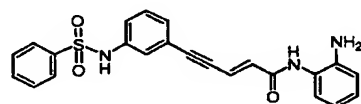
20



(4)



(5)



(6)

25 Measurement of the enzymatic activity of a histone deacetylase can be achieved using known methodologies. For example, Yoshida *et al.*, *J. Biol. Chem.*, 265: 17174-17179 (1990), describes the assessment of histone deacetylase

5 enzymatic activity by the detection of acetylated histones in trichostatin A treated cells. Taunton *et al.*, *Science*, 272: 408-411 (1996), similarly describes methods to measure histone deacetylase enzymatic activity using endogenous and recombinant HDAC-1. Both of these references are hereby incorporated by reference in their entirety.

10 In some preferred embodiments, the histone deacetylase inhibitor interacts with and reduces the activity of all histone deacetylases in the cell. In some other preferred embodiments according to this aspect of the invention, the histone deacetylase inhibitor interacts with and reduces the activity of fewer than all histone deacetylases in the cell. In certain preferred embodiments, the  
15 inhibitor interacts with and reduces the activity of one histone deacetylase (e.g., HDAC-1), but does not interact with or reduce the activities of other histone deacetylases (e.g., HDAC-2, HDAC-3, HDAC-4, HDAC-5, HDAC-6, HDAC-7, and HDAC-8). As discussed below, certain particularly preferred histone deacetylase inhibitors are those that interact with and reduce the enzymatic  
20 activity of a histone deacetylase that is involved in tumorigenesis. Certain other preferred histone deacetylase inhibitors interact with and reduce the enzymatic activity of a fungal histone deacetylase.

Preferably, the method according to the third aspect of the invention causes an inhibition of cell proliferation of the contacted cells. The phrase  
25 "inhibiting cell proliferation" is used to denote an ability of an inhibitor of histone deacetylase to retard the growth of cells contacted with the inhibitor as compared to cells not contacted. An assessment of cell proliferation can be made by counting contacted and non-contacted cells using a Coulter Cell Counter (Coulter, Miami, FL) or a hemacytometer. Where the cells are in a solid growth  
30 (e.g., a solid tumor or organ), such an assessment of cell proliferation can be made by measuring the growth with calipers and comparing the size of the growth of contacted cells with non-contacted cells.

Preferably, growth of cells contacted with the inhibitor is retarded by at least 50% as compared to growth of non-contacted cells. More preferably, cell

5 proliferation is inhibited by 100% (*i.e.*, the contacted cells do not increase in number). Most preferably, the phrase "inhibiting cell proliferation" includes a reduction in the number or size of contacted cells, as compared to non-contacted cells. Thus, an inhibitor of histone deacetylase according to the invention that inhibits cell proliferation in a contacted cell may induce the contacted cell to  
10 undergo growth retardation, to undergo growth arrest, to undergo programmed cell death (*i.e.*, to apoptose), or to undergo necrotic cell death.

The cell proliferation inhibiting ability of the histone deacetylase inhibitors according to the invention allows the synchronization of a population of asynchronously growing cells. For example, the histone deacetylase  
15 inhibitors of the invention may be used to arrest a population of non-neoplastic cells grown *in vitro* in the G1 or G2 phase of the cell cycle. Such synchronization allows, for example, the identification of gene and/or gene products expressed during the G1 or G2 phase of the cell cycle. Such a synchronization of cultured cells may also be useful for testing the efficacy of a new transfection protocol,  
20 where transfection efficiency varies and is dependent upon the particular cell cycle phase of the cell to be transfected. Use of the histone deacetylase inhibitors of the invention allows the synchronization of a population of cells, thereby aiding detection of enhanced transfection efficiency.

In some preferred embodiments, the contacted cell is a neoplastic cell. The  
25 term "neoplastic cell" is used to denote a cell that shows aberrant cell growth. Preferably, the aberrant cell growth of a neoplastic cell is increased cell growth. A neoplastic cell may be a hyperplastic cell, a cell that shows a lack of contact inhibition of growth *in vitro*, a benign tumor cell that is incapable of metastasis *in vivo*, or a cancer cell that is capable of metastasis *in vivo* and that may recur after  
30 attempted removal. The term "tumorigenesis" is used to denote the induction of cell proliferation that leads to the development of a neoplastic growth. In some embodiments, the histone deacetylase inhibitor induces cell differentiation in the contacted cell. Thus, a neoplastic cell, when contacted with an inhibitor of

5 histone deacetylase may be induced to differentiate, resulting in the production of a daughter cell that is phylogenetically more advanced than the contacted cell.

In some preferred embodiments, the contacted cell is in an animal. Thus, the invention provides a method for treating a cell proliferative disease or condition in an animal, comprising administering to an animal in need of such  
10 treatment a therapeutically effective amount of a histone deacetylase inhibitor of the invention. Preferably, the animal is a mammal, more preferably a domesticated mammal. Most preferably, the animal is a human.

The term "cell proliferative disease or condition" is meant to refer to any condition characterized by aberrant cell growth, preferably abnormally  
15 increased cellular proliferation. Examples of such cell proliferative diseases or conditions include, but are not limited to, cancer, restenosis, and psoriasis. In particularly preferred embodiments, the invention provides a method for inhibiting neoplastic cell proliferation in an animal comprising administering to an animal having at least one neoplastic cell present in its body a therapeutically  
20 effective amount of a histone deacetylase inhibitor of the invention.

It is contemplated that some compounds of the invention have inhibitory activity against a histone deacetylase from a protozoal source. Thus, the invention also provides a method for treating or preventing a protozoal disease or infection, comprising administering to an animal in need of such treatment a  
25 therapeutically effective amount of a histone deacetylase inhibitor of the invention. Preferably the animal is a mammal, more preferably a human. Preferably, the histone deacetylase inhibitor used according to this embodiment of the invention inhibits a protozoal histone deacetylase to a greater extent than it inhibits mammalian histone deacetylases, particularly human histone  
30 deacetylases.

The present invention further provides a method for treating a fungal disease or infection comprising administering to an animal in need of such treatment a therapeutically effective amount of a histone deacetylase inhibitor of the invention. Preferably the animal is a mammal, more preferably a human.

5 Preferably, the histone deacetylase inhibitor used according to this embodiment of the invention inhibits a fungal histone deacetylase to a greater extent than it inhibits mammalian histone deacetylases, particularly human histone deacetylases.

10 The term "therapeutically effective amount" is meant to denote a dosage sufficient to cause inhibition of histone deacetylase activity in the cells of the subject, or a dosage sufficient to inhibit cell proliferation or to induce cell differentiation in the subject. Administration may be by any route, including, without limitation, parenteral, oral, sublingual, transdermal, topical, intranasal, intratracheal, or intrarectal. In certain particularly preferred embodiments,  
15 compounds of the invention are administered intravenously in a hospital setting. In certain other preferred embodiments, administration may preferably be by the oral route.

When administered systemically, the histone deacetylase inhibitor is preferably administered at a sufficient dosage to attain a blood level of the  
20 inhibitor from about 0.01 M to about 100 M, more preferably from about 0.05 M to about 50 M, still more preferably from about 0.1 M to about 25 M, and still yet more preferably from about 0.5 M to about 25 M. For localized administration, much lower concentrations than this may be effective, and much higher concentrations may be tolerated. One of skill in the art will appreciate that the  
25 dosage of histone deacetylase inhibitor necessary to produce a therapeutic effect may vary considerably depending on the tissue, organ, or the particular animal or patient to be treated.

In certain preferred embodiments of the fifth and sixth aspects of the invention, the method further comprises contacting the cell with an antisense  
30 oligonucleotide that inhibits the expression of a histone deacetylase. The combined use of a nucleic acid level inhibitor (*i.e.*, antisense oligonucleotide) and a protein level inhibitor (*i.e.*, inhibitor of histone deacetylase enzyme activity) results in an improved inhibitory effect, thereby reducing the amounts of the inhibitors required to obtain a given inhibitory effect as compared to the



5 amounts necessary when either is used individually. The antisense oligonucleotides according to this aspect of the invention are complementary to regions of RNA or double-stranded DNA that encode HDAC-1, HDAC-2, HDAC-3, HDAC-4, HDAC-5, HDAC-6, HDAC7, and/or HDAC-8.

For purposes of the invention, the term "oligonucleotide" includes  
10 polymers of two or more deoxyribonucleosides, ribonucleosides, or 2'-O-substituted ribonucleoside residues, or any combination thereof. Preferably, such oligonucleotides have from about 6 to about 100 nucleoside residues, more preferably from about 8 to about 50 nucleoside residues, and most preferably from about 12 to about 30 nucleoside residues. The nucleoside residues may be  
15 coupled to each other by any of the numerous known internucleoside linkages. Such internucleoside linkages include without limitation phosphorothioate, phosphorodithioate, alkylphosphonate, alkylphosphonothioate, phosphotriester, phosphoramidate, siloxane, carbonate, carboxymethylester, acetamidate, carbamate, thioether, bridged phosphoramidate, bridged methylene  
20 phosphonate, bridged phosphorothioate and sulfone internucleoside linkages. In certain preferred embodiments, these internucleoside linkages may be phosphodiester, phosphotriester, phosphorothioate, or phosphoramidate linkages, or combinations thereof. The term oligonucleotide also encompasses such polymers having chemically modified bases or sugars and/or having  
25 additional substituents, including without limitation lipophilic groups, intercalating agents, diamines and adamantane. For purposes of the invention the term "2'-O-substituted" means substitution of the 2' position of the pentose moiety with an -O-lower alkyl group containing 1-6 saturated or unsaturated carbon atoms, or with an -O-aryl or allyl group having 2-6 carbon atoms,  
30 wherein such alkyl, aryl or allyl group may be unsubstituted or may be substituted, *e.g.*, with halo, hydroxy, trifluoromethyl, cyano, nitro, acyl, acyloxy, alkoxy, carboxyl, carbalkoxyl, or amino groups; or such 2' substitution may be with a hydroxy group (to produce a ribonucleoside), an amino or a halo group,

5 but not with a 2'-H group. The term "oligonucleotide" also encompasses linked nucleic acid and peptide nucleic acid.

Particularly preferred antisense oligonucleotides utilized in this aspect of the invention include chimeric oligonucleotides and hybrid oligonucleotides.

For purposes of the invention, a "chimeric oligonucleotide" refers to an  
10 oligonucleotide having more than one type of internucleoside linkage. One preferred example of such a chimeric oligonucleotide is a chimeric oligonucleotide comprising a phosphorothioate, phosphodiester or phosphorodithioate region, preferably comprising from about 2 to about 12 nucleotides, and an alkylphosphonate or alkylphosphonothioate region (see *e.g.*,  
15 Pederson *et al.* U.S. Patent Nos. 5,635,377 and 5,366,878). Preferably, such chimeric oligonucleotides contain at least three consecutive internucleoside linkages selected from phosphodiester and phosphorothioate linkages, or combinations thereof.

For purposes of the invention, a "hybrid oligonucleotide" refers to an  
20 oligonucleotide having more than one type of nucleoside. One preferred example of such a hybrid oligonucleotide comprises a ribonucleotide or 2'-O-substituted ribonucleotide region, preferably comprising from about 2 to about 12 2'-O-substituted nucleotides, and a deoxyribonucleotide region. Preferably, such a hybrid oligonucleotide will contain at least three consecutive  
25 deoxyribonucleosides and will also contain ribonucleosides, 2'-O-substituted ribonucleosides, or combinations thereof (see *e.g.*, Metelev and Agrawal, U.S. Patent No. 5,652,355).

The exact nucleotide sequence and chemical structure of an antisense  
oligonucleotide utilized in the invention can be varied, so long as the  
30 oligonucleotide retains its ability to inhibit expression of the gene of interest. This is readily determined by testing whether the particular antisense oligonucleotide is active by quantitating the mRNA encoding a product of the gene, or in a Western blotting analysis assay for the product of the gene, or in an activity assay for an enzymatically active gene product, or in a soft agar growth

5 assay, or in a reporter gene construct assay, or an *in vivo* tumor growth assay, all of which are described in detail in this specification or in Ramchandani *et al.* (1997) Proc. Natl. Acad. Sci. USA 94: 684-689.

Antisense oligonucleotides utilized in the invention may conveniently be synthesized on a suitable solid support using well known chemical approaches,  
10 including H-phosphonate chemistry, phosphoramidite chemistry, or a combination of H-phosphonate chemistry and phosphoramidite chemistry (*i.e.*, H-phosphonate chemistry for some cycles and phosphoramidite chemistry for other cycles). Suitable solid supports include any of the standard solid supports used for solid phase oligonucleotide synthesis, such as controlled-pore glass  
15 (CPG) (see, *e.g.*, Pon, R.T. (1993) Methods in Molec. Biol. 20: 465-496).

Particularly, preferred oligonucleotides have nucleotide sequences of from about 13 to about 35 nucleotides which include the nucleotide sequences shown in Tables 1-3. Yet additional particularly preferred oligonucleotides have nucleotide sequences of from about 15 to about 26 nucleotides of the nucleotide  
20 sequences shown in Tables 1-3.

5

**Table 1**

SEQ ID NO.	SEQUENCE	TARGET (**)
1	5'-GAG ACA GCA GCA CCA GCG GG -3'	17-36
2	5'-ATG ACC GAG TGG GAG ACA GC-3'	21-49
3	5'-GGA TGA CCG AGT GGG AGA CA-3'	31-50
4	5'-CAG GAT GAC CGA GTG GGA GA -3'	33-52
5	5'-TGT GTT CTC AGG ATG ACC GA-3'	41-60
6	5'-GAG TGA CAG AGA CGC TCA GG-3'	62-81
7	5'-TTC TGG CTT CTC CTC CTT GG-3'	1504-1523
8	5'-CTT GAC CTC CTC CTT GAC CC-3'	1531-1550
9	5'-GGA AGC CAG AGC TGG AGA GG-3'	1565-1584
10	5'-GAA ACG TGA GGG ACT CAG CA-3'	1585-1604
11	5'-CCG TCG TAG TAG TAA CAG ACT TT-3'	138-160
12	5'-TGT CCA TAA TAG TAA TTT CCA A-3'	166-187
13	5'-CAG CAA ATT ATG AGT CAT GCG GAT TC-3'	211-236

(\*\*) target reference numbering is in accordance with HDAC-1, GenBank Accession Number U50079.

**Table 2**

SEQ ID NO.	SEQUENCE	TARGET (***)
14	5'-CTC CTT GAC TGT ACG CCA TG-3'	1-20
15	5'-TGC TGC TGC TGC TGC TGC CG-3'	121-141
16	5'-CCT CCT GCT GCT GCT GCT GC-3'	132-152
17	5'-CCG TCG TAG TAG TAG CAG ACT TT-3'	138-160
18	5'-TGT CCA TAA TAA TAA TTT CCA A-3'	166-187
19	5'-CAG CAA GTT ATG GGT CAT GCG GAT TC-3'	211-236
20	5'-GGT TCC TTT GGT ATC TGT TT-3'	1605-1625

(\*\*\*) target reference numbering is in accordance with HDAC-2, GenBank Accession Number U31814.

10

5

**Table 3**

SEQ ID NO.	SEQUENCE	TARGET (***)
21	5'-GCT GCC TGC CGT GCC CAC CC-3'	514-533

(\*\*\*) target reference numbering is in accordance with HDAC-4

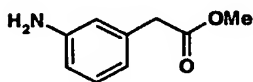
The following examples are intended to further illustrate certain preferred  
embodiments of the invention, and are not intended to limit the scope of the  
invention.

10

## EXAMPLES

### Preparation of amines

#### Methyl-3-aminophenylacetate (1)



15

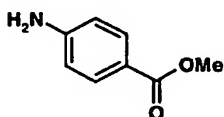
To a solution of 3-aminophenylacetic acid (3 g, 19.85 mmol) in methanol (50 mL) at room temperature was added HCl conc. (37%, 7.5 mL). The mixture was stirred 6 h at room temperature then treated with a saturated aqueous solution of NaHCO<sub>3</sub>. The solvent was removed under reduced pressure then the aqueous phase was extracted several times with CH<sub>2</sub>Cl<sub>2</sub>. The combined organic  
extracts were dried over (MgSO<sub>4</sub>) and evaporated. The crude mixture was  
purified by flash chromatography using hexane/AcOEt (1:1) yielding 1 as a  
yellow oil (3.06 g, 79%).

20

<sup>1</sup>H NMR: (300 MHz, CDCl<sub>3</sub>): 7.10 (t, J = 8Hz, 1H), 6.68-6.58 (m, 3H), 3.69-3.65 (m, 5H), 3.53 (s, 2H).

25

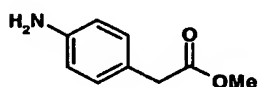
## 5 Methyl-4-aminophenyl benzoate (2)



To a solution of 4-aminobenzoic acid (10 g, 72.92 mmol) in methanol (200 mL) at room temperature was added HCl conc. (37%, 25 mL). The solution mixture was heated overnight at 70 °C. Once the solution was clear (completed) the reaction was treated with a saturated aqueous solution of NaHCO<sub>3</sub> and Na<sub>2</sub>CO<sub>3</sub> powder until pH 9. The solvent was then evaporated under reduced pressure and the aqueous phase was extracted several times with AcOEt. The combined organic extracts were dried over (MgSO<sub>4</sub>) and evaporated. The crude product 2 (9.30 g 85 %) was obtained as a beige solid and was clean enough to use without further purification.

<sup>1</sup>H NMR: (300 MHz, CDCl<sub>3</sub>): 7.85 (d, J = 8Hz, 2H), 6.63 (d, J = 8Hz, 2H), 4.04 (broad s. 2H), 3.85 (s. 3H).

## Methyl-4-aminophenylacetate (3)



20

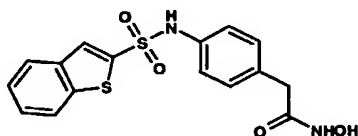
To a solution of 4-aminophenylacetic acid (10 g, 66.2 mmol) in methanol (150 mL) at room temperature was added HCl conc. (37% 25 mL). The mixture became yellow and was stirred overnight. The reaction mixture was then quenched with a saturated aqueous solution of NaHCO<sub>3</sub>. The methanol was evaporated under reduced pressure and the aqueous layer was extracted several times with AcOEt. The combined organic extracts were dried over (MgSO<sub>4</sub>) and evaporated. The crude residue was purified by flash chromatography using hexane/AcOEt (4:1) as solvent mixture yielding 3 as a yellow oil (9.44 g, 74%).

25

- 5 <sup>1</sup>H NMR: (300 MHz, CDCl<sub>3</sub>): 7.05 (d, J = 10Hz, 2H), 6.65 (d, J = 10Hz, 2H), 3.65 (s, 3H), 3.63 (broad s, 2H), 3.51 (s, 2H).

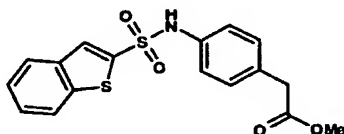
**Example 1:**

**2-[4-benzo[b]thiophene-2-sulfonylamino)-phenyl]-N-hydroxy- acetamide (4)**



10

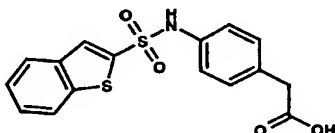
**Step 1: Methyl-2-[4-benzo[b]thiophene-2-sulfonylamino)-phenyl]-acetate (5)**



- To a solution of 3 (500 mg, 2.56 mmol), in CH<sub>2</sub>Cl<sub>2</sub> (8 mL) at room temperature were added Et<sub>3</sub>N (712  $\mu$ L, 5.12 mmol) followed by 2- benzothiophenesulfonyl chloride (712 mg, 3.07 mmol). The mixture was stirred overnight at room temperature then quenched with a saturated aqueous solution of NaHCO<sub>3</sub>. The phases were separated and the aqueous layer was extracted several times with CH<sub>2</sub>Cl<sub>2</sub>. The combined organic extracts were dried over (MgSO<sub>4</sub>) and evaporated. The mixture of the mono and bis alkylated products were dissolved in methanol (~8 mL) and NaOMe was added (691 mg, 12.8 mmol). The resulting mixture was heated at 60 °C for 30 min the HCl 1N was added until pH 2. Then a saturated aqueous solution of NaHCO<sub>3</sub> was added until pH 7-8. The solvent was evaporated under reduced pressure then the aqueous layer was extracted several times with CH<sub>2</sub>Cl<sub>2</sub>. The combined organic extracts were dried over (MgSO<sub>4</sub>) and evaporated. The residue was purified by flash chromatography using toluene/AcOEt 7:3 as solvent mixture and a second flash chromatography using CH<sub>2</sub>Cl<sub>2</sub>/acetone 98:2 as solvent yielding the title compound 5 as yellowish powder (487 mg, 53 %).

- 5 <sup>1</sup>H NMR: (300 MHz, CDCl<sub>3</sub>): 7.80 (d, J = 8 Hz, 2H), 7.75 (s, 1H), 7.44 (m, 2H), 7.14 (m, 4H), 6.79 (broad s, 1H) 3.67 (s, 3H), 3.56 (s, 2H)

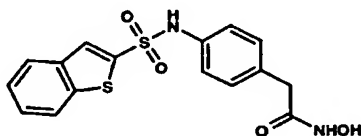
Step 2: 2-[4-benzo[b]thiophene-2-sulfonylamino)-phenyl]-acetic acid (6)



- To a solution of 5 from step 1 (451 mg, 1.25 mmol) in a solvent mixture of THF (20 mL) and H<sub>2</sub>O (20 mL) at room temperature was added LiOH (524 mg, 12.5 mmol). The mixture was stirred for 2 h at room temperature and then was treated with a saturated aqueous solution of NH<sub>4</sub>Cl. The resulting solution was extracted several times with AcOEt. The combined organic extracts were dried over (MgSO<sub>4</sub>). The crude residue was then purified by flash chromatography using CH<sub>2</sub>Cl<sub>2</sub>/MeOH (9:1) as solvent mixture yielding the title compound 6 as white solid (404 mg, 93%).
- 15

<sup>1</sup>H NMR: (300 MHz, DMSO-*d*<sub>6</sub>): 8.03 (d, J = 8 Hz, 1H), 7.97 (d, J = 7 Hz, 1H), 7.92 (s, 1H), 7.50-7.45 (m, 2H), 7.13-7.06 (m, 4H), 3.44 (s, 2H).

- 20 Step 3: 2-[4-benzo[b]thiophene-2-sulfonylamino)-phenyl]-N-hydroxy- acetamide (4)



**Method A :**

- To a solution of 6 (150 mg, 0.432 mmol) in a solvent mixture of CH<sub>2</sub>Cl<sub>2</sub> (10 mL) and THF (5 mL) was added at room temperature 1,3-dicyclohexylcarbodiimide (DCC, 116 mg, 0.563 mmol). The reaction mixture was stirred 30 min at room temperature then NH<sub>4</sub>OTHP (76 mg, 0.650 mmol)
- 25

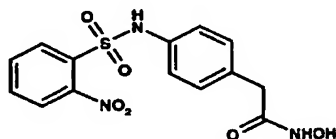


5 and dimethylaminopyridine (DMAP, 5 mg) were added. The solution was stirred over night at room temperature and the solvents were evaporated under reduced pressure. The crude material was purified by flash chromatography using  $\text{CH}_2\text{Cl}_2/\text{MeOH}$  (9:1) as solvent. The residue was dissolved in MeOH (~10 mL) and 10-camphorsulfonic acid (CSA, 100 mg, 0.432 mmol) was added. The  
10 mixture was stirred at room temperature overnight then treated with a saturated aqueous solution of  $\text{NaHCO}_3$ . The solvent was evaporated under reduced pressure and the aqueous phase was extracted several times with  $\text{CH}_2\text{Cl}_2$  (3X) and AcOEt (3X). The combined organic extracts were dried over ( $\text{MgSO}_4$ ) and evaporated. The crude product was purified by preparative high pressure liquid  
15 chromatography on reversed phase silica gel using a gradient of water/ $\text{CH}_3\text{CN}$  (10-65%) yielding the title compound 4 as yellowish solid (70 mg, 45%).  
'H NMR (300 MHz,  $\text{CD}_3\text{OD}$ ): 7.92- 7.88 (m, 2H), 7.80 (s, 1H), 7.50-7.45 (m, 2H), 7.23-7.16 (m, 4H) 3.35 (s, 2H).

20 Except where otherwise indicated, the following compounds were prepared by procedures analogous to those described in Example 1, but substituting the sulfonyl chloride indicated for 2-benzothiophenesulfonyl chloride in step 1.

25 **Example 2:**

**2-[4-(2-nitrobenzenesulfonylamino)-phenyl]-N-hydroxy-acetamide (7)**



Sulfonyl chloride: 2-nitrobenzenesulfonyl chloride

Yield: Step 1: 82%

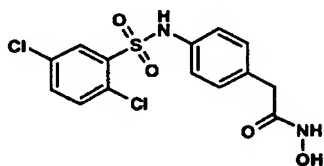
30 Yield: Step 2: 99%

5 Yield: Step 3: 19%

<sup>1</sup>H NMR (300 MHz, DMSO-*d*<sub>6</sub>); δ 10.59 (s, 1H); 8.78 (s, 1H); 7.94 (s, 2H), 7.81 (s, 2H), 7.20-7.02 (m, 4H); 3.13 (s, 2H).

**Example 3:**

10 2-[4-(2,5-dichlorobenzenesulfonylamino)-phenyl]-N-hydroxy- acetamide (8)



Sulfonyl chloride: 2,5-Dichlorobenzenesulfonyl chloride

Yield: Step 1: 66%

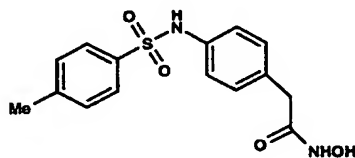
Yield: Step 2: 96%

15 Yield: Step 3: 66%

<sup>1</sup>H NMR (300 MHz, DMSO-*d*<sub>6</sub>); δ 10.68 (s, 1H), 8.88 (s, 1H), 7.95 (s, 1H), 7.67 (s, 2H); 7.13 (d, 2H, J=8Hz), 7.02 (d, 2H, J=8Hz), 3.16 (s, 2H)

**Example 4:**

20 2-[4-(4-methylbenzenesulfonylamino)-phenyl]-N-hydroxy-acetamide (9)



Sulfonyl chloride: 4-methylbenzenesulfonyl chloride

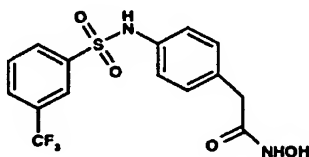
Step 1: Yield 100%

5 Step 2: 2-[4-(4-methylbenzenesulfonylamino)-phenyl]-N-hydroxy-acetamide (9)**Method B :**

To a solution of methyl-2-[4-(4-methylbenzenesulfonylamino)]phenylacetate (459 mg, 1.44 mmol) in methanol (10 mL), at room temperature were added hydroxylamine hydrochloride (200 mg, 2.88 mmol) followed by sodium methoxide (389 mg, 7.19 mmol). The resulting mixture was heated overnight at 60 °C then treated with HCl (1N) until pH 2. The solvent was evaporated under reduced pressure then the aqueous phase was extracted several times with CH<sub>2</sub>Cl<sub>2</sub>. The combined organic extracts were dried over (MgSO<sub>4</sub>) then evaporated. The crude mixture was purified by flash chromatography using CH<sub>2</sub>Cl<sub>2</sub>/MeOH (9:1) as solvent mixture yielding the title compound 9 (244 mg, 53 %) as a white powder.

<sup>1</sup>H NMR (300 MHz, acetone-d<sub>6</sub>); δ 7.68(d, J = 8Hz, 2H); 7.29 (d, J = 8 Hz, 2H), 7.15 (br. s, 4H), 3.33(s, 2H, CH<sub>2</sub>), 2.33 (s, 3H, CH<sub>3</sub>).

20 The following compounds were prepared following procedures analogous to those described in Example 1, step 1, and Example 4, step 2 (Method B), but substituting the sulfonyl chloride indicated for 2-benzothiophenesulfonyl chloride in step 1.

25 Example 5:**2-[4-(3-trifluoromethylbenzenesulfonylamino)-phenyl]-N-hydroxy acetamide (10)**

Sulfonyl chloride: 3-trifluoromethylbenzenesulfonyl chloride

5 Yield: Step 1: 70%

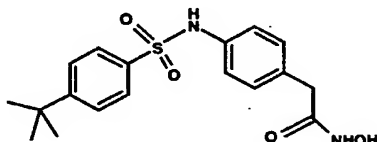
Yield: Step 2: 49%

<sup>1</sup>H NMR (300 MHz, acetone-*d*<sub>6</sub>);  $\delta$  = 8.09 (s, 1H), 8.05 (d, 1H, J=8Hz), 7.95 (d, 1H, J=8Hz); 7.77 (t, 1H, J=8Hz); 7.21 (d, 2H, J=8Hz), 7.13 (d, 2H, J=8Hz); 3.35 (s, 2H, CH<sub>2</sub>)

10

**Example 6:**

**2-[4-(tert-butylsulfonylamino)-phenyl] -N-hydroxy-acetamide (11)**



Sulfonyl chloride: 4-tert-butylsulfonyl chloride

15 Yield: Step 1: 76%

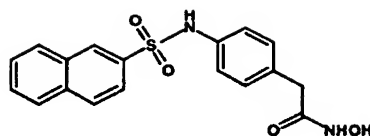
Yield: Step 2: 40%

<sup>1</sup>H NMR (300 MHz, acetone-*d*<sub>6</sub>);  $\delta$  7.75 (d, 2H, J=9Hz), 7.56 (d, 2H, J=9Hz); 7.17 (s, 4H); 3.34 (s, 2H), 1.29 (s, 9H)

20 The following compound was prepared following procedures analogous to those described in Example 1, steps 1-2, substituting the sulfonyl chloride indicated for 2-benzothiophenesulfonyl chloride in step 1, followed by hydroxamic acid formation using **Method C**

25 **Example 7:**

**2-[2-(naphthylsulfonylamino)-phenyl]-N-hydroxy-acetamide (12)**



5

Sulfonyl chloride: 2-naphthylsulfonyl chloride

Yield: Step 1: 100%

Yield: Step 2: 100%

10 Step 3 : 2-[2-(naphthylsulfonylamino)-phenyl]-N-hydroxy-acetamide (12)

**Method C:**

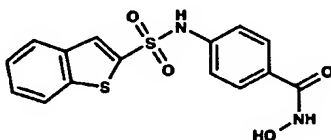
To a solution of 2-[2-(naphthylsulfonylamino)]-phenylacetic acid (191 mg, 0.563 mmol) in  $\text{CH}_2\text{Cl}_2$  (20 mL) at room temperature were added DMF (1 drop) followed by  $(\text{COCl})_2$  (250  $\mu\text{L}$ , 2.81 mmol). The mixture became yellow and solidification appeared. The reaction was stirred 90 min at room temperature then  $(\text{COCl})_2$  was added until no bubbling ( $\sim 1\text{mL}$ ). Then the solvents were evaporated under reduced pressure. The crude material was dissolved in  $\text{CH}_2\text{Cl}_2$  and  $\text{TMSONH}_2$  (3 mL) was added to the solution. The reaction was exothermic and the resulting mixture was stirred 2 h at room temperature then treated with HCl (1N) until pH 2. The phases were separated and the aqueous layer was extracted several times with  $\text{CH}_2\text{Cl}_2$ . The combined organic extracts were dried over  $(\text{MgSO}_4)$  then evaporated. The crude compound was purified 3 times by flash chromatography using  $\text{CH}_2\text{Cl}_2/\text{MeOH}$  (9:1) as solvent mixture then another purification using preparative high pressure liquid chromatography using reversed phase chromatography with a gradient of water/ $\text{CH}_3\text{CN}$  (10-70%) yielding the title compound 12 as a white powder (29 mg, 15 %).

$^1\text{H}$  NMR (300 MHz, acetone- $d_6$ );  $\delta$  9.13 (s, 1H), 8.42 (s, 1H), 8.08-7.97 (m, 3H), 7.82 (dd, 1H,  $J=9\text{Hz}, 1.5\text{Hz}$ ), 7.70-7.63 (m, 2H), 7.21-7.14 (m, 4H), 3.50 (s, 2H)

- 5           The following compound was prepared following procedures analogous to those described in Example 1, steps 1-2, substituting the indicated sulfonyl chloride and amine indicated for 2-benzothiophenesulfonyl chloride and 3 in step 1, followed by hydroxamic acid formation using Method D.

10   **Example 8:**

**N-hydroxy-[4-benzo[b]thiophene-2-sulfonylamino)-phenyl]-benzamide (13)**



Sulfonyl chloride: 2-Benzothiophenesulfonyl chloride

Amine: Methyl-4-aminobenzoate (2)

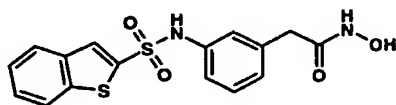
- 15   Yield: Step 1: 80%  
Yield: Step 2: 69%

**Step 3: N-hydroxy-[4-benzo[b]thiophene-2-sulfonylamino)-phenyl]-benzamide (13)**

20   **Method D:**

- To a solution of 2-[4-benzo[b]thiophene-2-sulfonylamino]benzoic acid (300 mg, .90 mmol) in DMF (20 mL) at room temperature were added 1-(3-dimethyl-aminopropyl)-3-ethylcarbodiimide hydrochloride (EDC, 207 mg, 1.08 mmol), and 1-Hydroxybenzotriazole hydrate (HOBt, 182 mg, 1.35 mmol). The mixture was stirred 20 min. at room temperature then  $\text{NH}_4\text{OTHP}$  (158 mg, 1.35 mmol) was added. The resulting mixture was heated at 50 °C for 24 h then stirred at room temperature for 24 h. The DMF solvent was evaporated under reduced pressure and the residue was dissolved in  $\text{CH}_2\text{Cl}_2$  and washed with brine or a saturated aqueous solution of  $\text{NaHCO}_3$ . The combined organic  
30   extracts were dried over ( $\text{MgSO}_4$ ) then condensed. The crude compound was

- 5 purified by flash chromatography using  $\text{CH}_2\text{Cl}_2/\text{MeOH}$  (9:1) as solvent mixture. The residue was then dissolved in methanol (20 mL) then 10-camphorsulfonic acid (CSA, 100 mg, .45 mmol) was added. The mixture was stirred 2 h at room temperature then the solvents were evaporated under reduced pressure at room temperature to avoid thermal decomposition. The crude was purified by flash
- 10 chromatography using  $\text{CH}_2\text{Cl}_2/\text{MeOH}$  (9:1) as solvent mixture. A second purification was performed using a preparative high pressure liquid chromatography using a gradient of water/ $\text{CH}_3\text{CN}$  (10-85%) as solvent giving the title compound **13** as a red solid (212 mg, 68%).
- $^1\text{H}$  NMR (300 MHz, acetone- $d_6$ );  $\delta$  10.69 (s, 1H), 9.70 (s, 1H); 8.01-7.97 (m, 3H),
- 15 7.77 (d, 2H,  $J=9\text{Hz}$ ); 7.55-7.39 (m, 4H).

**Example 9:****2-[3-benzo[b]thiophene-2-sulfonylamino)-phenyl] N-hydroxy-acetamide (14)**

20

Sulfonyl chloride: 2-Benzothiophenesulfonyl chloride

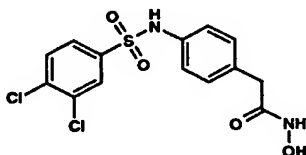
Amine: Methyl-3-aminophenyl acetate (1)

Yield: Step 1: 88%

Yield: Step 2: 89%

25 Yield: Step 3: 32%

$^1\text{H}$  NMR (300 MHz, Acetone- $d_6$ );  $\delta$  10.20 (s, 1H), 8.33 (s, 1H), 7.99-7.95 (m, 3H), 7.53-7.43 (m, 2H), 7.35 (s, 1H), 7.21-7.17 (m, 2H), 7.06-7.03 (m, 1H), 3.38 (s, 2H)

5 **Example 10:****2-[4-(3,4-dichlorobenzenesulfonylamino)-phenyl]-N-hydroxy- acetamide (15)**

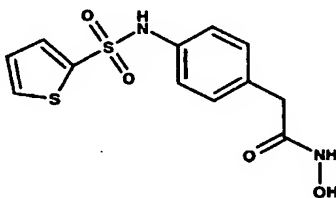
Sulfonyl chloride: 3,4-Dichlorobenzenesulfonyl chloride

Yield: Step 1: 80%

10 Yield: Step 2: 67%

Yield: Step 3: 81%

<sup>1</sup>H NMR (300 MHz, acetone-*d*<sub>6</sub>); δ 10.12 (s, 1H), 9.15 (s, 1H), 7.92 (s, 1H), 7.74-7.71 (m, 2H), 7.23 (d, 2H, J=9Hz), 7.14 (d, 2H, J=9Hz), 3.36 (s, 2H)

15 **Example 11:****2-[4-(2-Thiophenesulfonylamino)-phenyl]-N-hydroxy-acetamide (16)**

Sulfonyl chloride: 2-Thiophenesulfonyl chloride

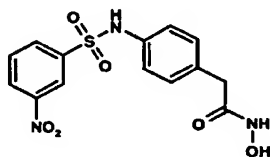
Yield: Step 1: 84%

20 Yield: Step 2: 83%

Yield: Step 3: 9%

<sup>1</sup>H NMR (300 MHz, acetone-*d*<sub>6</sub>); δ 7.78 (s, 1H), 7.53 (s, 1H), 7.21 (s, 4H), 7.09 (s, 1H), 3.37 (s, 2H)



5 **Example 12:****2-[4-(3-nitrobenzenesulfonylamino)-phenyl]-N-hydroxy-acetamide (17)**

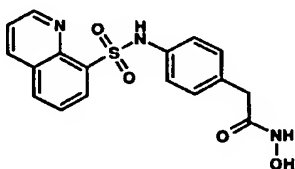
Sulfonyl chloride: 3-Nitrobenzenesulfonyl chloride

Yield: Step 1: 47%

10 Yield: Step 2: 34%

Yield: Step 3: 16%

<sup>1</sup>H NMR (300 MHz, acetone-*d*<sub>6</sub>); δ 9.31 (s, 1H), 8.59 (s, 1H), 8.45 (d, 1H, J=8 Hz), 8.16 (d, 1H, J=8Hz), 7.85 (t, 1H, J= 8Hz), 7.20-7.14 (m, 4H), 3.35 (s, 2H)

15 **Example 13:****2-[4-(8-quinolinesulfonylamino)-phenyl]-N-hydroxy-acetamide (18)**

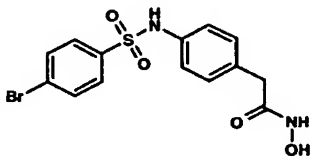
Sulfonyl chloride: 8-quinolinesulfonyl chloride

Yield: Step 1: 83%

20 Yield: Step 2: 78%

Yield: Step 3: 42%

<sup>1</sup>H NMR (300 MHz, acetone-*d*<sub>6</sub>); δ 9.17 (s, 1H), 8.50 (d, 1H, J=8Hz), 8.33 (d, 1H, J=8Hz), 8.21 (d, 1H, J=8Hz), 7.71-7.68 (m, 3H), 7.05 (broad s., 4H), 3.22 (s, 2H)

5 **Example 14:****2-[4-(4-bromobenzenesulfonylamino)-phenyl]-N-hydroxy-acetamide (19)**

Sulfonyl chloride: 4-Bromobenzenesulfonyl chloride

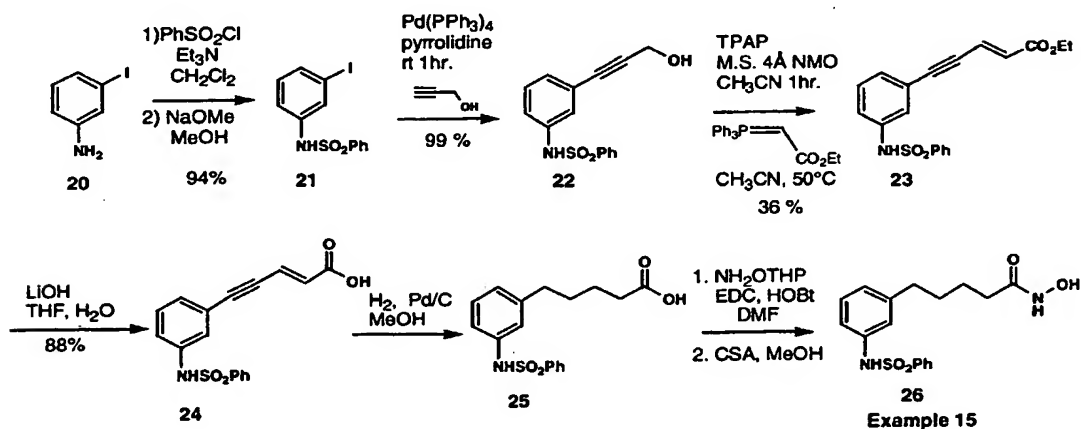
Yield: Step 1: 80%

10 Yield: Step 2: 81%

Yield: Step 3: 48%

<sup>1</sup>H NMR (300 MHz, acetone-*d*<sub>6</sub>); δ 9.17 (s, 1H), 7.72 (s, 4H), 7.19-7.14 (m, 4H), 3.35 (s, 2H)

15

**Example 15:****N-Hydroxy-5-[3-benzenesulfonylamino)-phenyl]-pentanamide (26)**

20

5 Step 1: 3-(benzenesulfonylamino)-phenyl iodide (21)

To a solution of 3-iodoaniline (5 g, 22.8 mmol), in  $\text{CH}_2\text{Cl}_2$  (100 mL), were added at room temperature  $\text{Et}_3\text{N}$  (6.97 mL) followed by benzenesulfonyl chloride (5.84 mL). The mixture was stirred 4 h then a white precipitate was formed. A saturated aqueous solution of  $\text{NaHCO}_3$  was added and the phases were  
10 separated. The aqueous layer was extracted several times with  $\text{CH}_2\text{Cl}_2$  and the combined extracts were dried over ( $\text{MgSO}_4$ ) then evaporated. The crude mixture was dissolved in MeOH (100 mL) and NaOMe (6 g), was added and the mixture was heated 1 h at 60 °C. The solution became clear with time and HCl (1N) was added. The solvent was evaporated under reduced pressure then the aqueous  
15 phase was extracted several times with  $\text{CH}_2\text{Cl}_2$ . The combined organic extracts were dried over ( $\text{MgSO}_4$ ) and evaporated. The crude material was purified by flash chromatography using (100%  $\text{CH}_2\text{Cl}_2$ ) as solvent yielding the title compound 21 (7.68g, 94 %) as yellow solid.  
'H NMR: (300 MHz,  $\text{CDCl}_3$ ): 7.82-7.78 (m, 2H), 7.60-7.55 (m, 1H), 7.50-7.42 (m, 4H), 7.10-7.06 (m, 1H), 6.96 (t, J = 8Hz, 1H), 6.87 (broad s, 1H).  
20

Step 2: 3-(benzenesulfonylamino)-phenyl-propargylic alcohol (22)

To a solution of 21 (500 mg, 1.39 mmol) in pyrrolidine (5 mL) at room temperature was added  $\text{Pd}(\text{PPh}_3)_4$  (80 mg, 0.069 mmol), followed by CuI (26 mg,  
25 0.139 mmol). The mixture was stirred until complete dissolution. Propargylic alcohol (162  $\mu\text{L}$ , 2.78 mmol) was added and stirred 6 h at room temperature. Then the solution was treated with a saturated aqueous solution of  $\text{NH}_4\text{Cl}$  and extracted several times with AcOEt. The combined organic extracts were dried over ( $\text{MgSO}_4$ ) then evaporated. The residue was purified by flash  
30 chromatography using hexane / AcOEt (1:1) as solvent mixture yielding 22 (395 mg, 99 %) as yellow solid.  
'H NMR: (300 MHz,  $\text{CDCl}_3$ ): 7.79-7.76 (m, 2H), 7.55-7.52 (m, 1H), 7.45 (t, J = 8Hz, 2H), 7.19-7.15 (m, 3H), 7.07-7.03 (m, 1H), 4.47 (s, 2H).

5

Step 3: 5-[3-(benzenesulfonylamino)-phenyl]-4-yn-2-pentenoate (23)

To a solution of **22** (2.75 g, 9.58 mmol) in CH<sub>3</sub>CN (150 mL) at room temperature were added 4-methylmorpholine N-oxide (NMO, 1.68 g, 14.37 mmol) followed by tetrapropylammonium perruthenate (TPAP, 336 mg, .958 mmol). The mixture was stirred at room temperature 3 h, and then filtrated through a Celite pad with a fritted glass funnel. To the filtrate carbethoxymethylenetriphenyl-phosphorane (6.66 g, 19.16 mmol) was added and the resulting solution was stirred 3 h at room temperature. The solvent was evaporated and the residue was dissolved in CH<sub>2</sub>Cl<sub>2</sub> and washed with a saturated aqueous solution of NH<sub>4</sub>Cl. The aqueous layer was extracted several times with CH<sub>2</sub>Cl<sub>2</sub>, then the combined organic extract were dried over (MgSO<sub>4</sub>) and evaporated. The crude material was purified by flash chromatography using hexane/AcOEt (1:1) as solvent mixture giving **23** (1.21 g, 36%) as yellow oil.

<sup>1</sup>H NMR: (300 MHz, CDCl<sub>3</sub>): 7.81 (d, J = 8Hz, 2H), 7.56-7.43 (m, 3H), 7.26-7.21 (m, 3H), 7.13-7.11 (m, 1H), 6.93 (d, J = 16 Hz, 1H), 6.29 (d, J = 16Hz, 1H), 4.24 (q, J = 7 Hz, 2H), 1.31 (t, J = 7Hz, 3H).

Step 4: 5-[3-(benzenesulfonylamino)-phenyl]-4-yn-2-pentenic acid (24)

To a solution of **23** (888 mg, 2.50 mmol) in a solvent mixture of THF (10 mL) and water (10 mL) at room temperature was added LiOH (1.04 g, 25.01 mmol). The resulting mixture was heated 2 h at 60 °C and treated with HCl (1N) until pH 2. The phases were separated and the aqueous layer was extracted several times with AcOEt. The combined organic extracts were dried over (MgSO<sub>4</sub>) then evaporated. The crude residue was purified by flash chromatography using CH<sub>2</sub>Cl<sub>2</sub>/MeOH (9:1) as solvent mixture yielding **24** (712 mg, 88 %), as white solid.

<sup>1</sup>H NMR: (300 MHz, DMSO-*d*<sub>6</sub>): 7.78-7.76 (m, 2H), 7.75-7.53 (m, 3H), 7.33-7.27 (m, 1H), 7.19-7.16 (m, 3H), 6.89 (d, J = 16 Hz, 1H), 6.33 (d, J = 16 Hz, 1H).

5

Step 5: 5-[3-(benzenesulfonylamino)-phenyl]-pentanoic acid (25)

To a solution **24** (100 mg, .306 mmol), in MeOH (6 mL) at room temperature was added a solution of Pd/C (10%, 20 mg, 1 mL MeOH). The reaction mixture was degassed and purged several times with H<sub>2</sub> gas with a final pressure of 60 psi. The mixture was stirred 2 h at room temperature then the resulting solution was filtrated over a silica gel pad with a fritted glass funnel. The solvent was evaporated yielding **25** (68 mg, 96%) and it was used directly for the next step without further purification.

<sup>1</sup>H NMR: (300 MHz, acetone-*d*<sub>6</sub>): 7.81-7.78 (m, 2H), 7.56-7.46 (m, 3H), 7.11-7.01 (m, 3H), 6.87 (d, J = 8Hz, 1H), 2.49 (broad s, 2H), 2.25 (broad s, 2H), 1.52 (broad s, 4H)

Step 6: N-Hydroxy-5-[3-benzenesulfonylamino)-phenyl]-pentanamide (26)

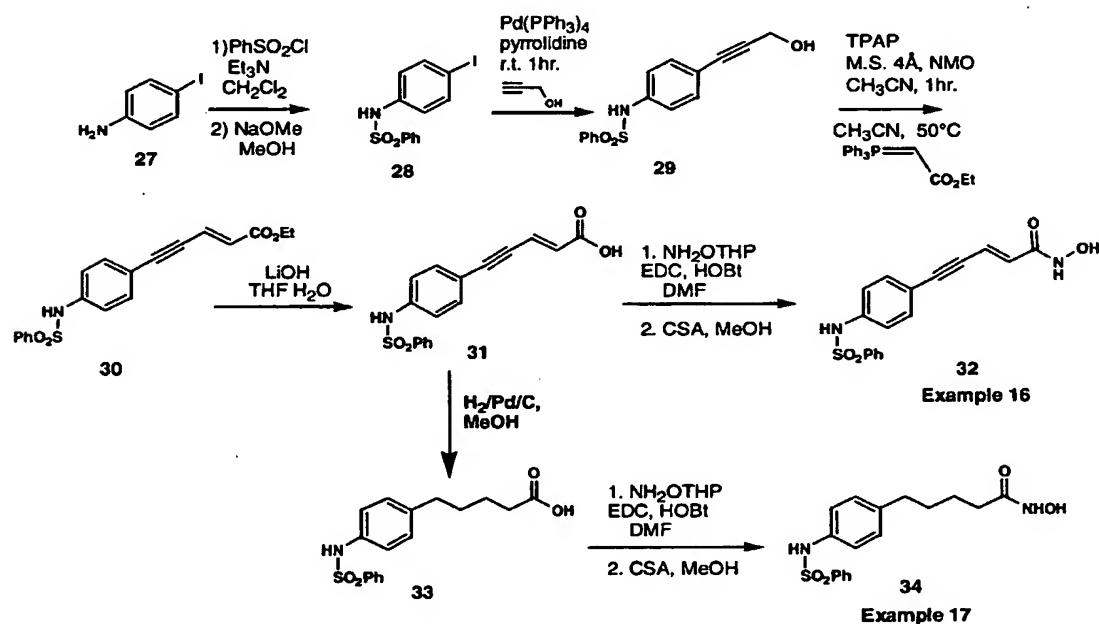
To a solution of **25** (100 mg, 300 mmol) in DMF (10 mL) at room temperature were added 1-(3-dimethylaminopropyl)-3-ethyl-carbodiimide hydrochloride (EDC, 69 mg, .320 mmol), and 1-hydroxybenzotriazole hydrate (HOBT, 61 mg, .45 mmol). The mixture was stirred 20 min. at room temperature then NH<sub>4</sub>OTHP (53 mg, .45 mmol) was added. The resulting mixture was heated overnight at 50 °C. The DMF solvent was evaporated under reduced pressure and the residue was dissolved in CH<sub>2</sub>Cl<sub>2</sub> and washed with brine or a saturated aqueous solution of NaHCO<sub>3</sub>. The combined organic extracts were dried over (MgSO<sub>4</sub>) then evaporated. The crude compound was purified by flash chromatography using hexane/acetone (7:3) as solvent mixture. The residue was then dissolved in MeOH (20 mL) then 10-camphorsulfonic acid (CSA, 35 mg, 150 mmol) was added. The mixture was stirred 2 h at room temperature then the solvents were evaporated under reduced pressure at room temperature to avoid thermal decomposition. The crude mixture was purified by flash

- 5 chromatography using  $\text{CH}_2\text{Cl}_2/\text{MeOH}$  (9:1) as solvent mixture giving 26 as a yellowish solid (62 mg, 60%).

$^1\text{H}$  NMR: (300 MHz, acetone- $d_6$ ): = 7.80-7.78 (m, 2H), 7.56-7.52 (m, 3H), 7.13-6.89 (m, 4H), 2.52 (broad s, 2H), 2.10 (broad s, 2H), 1.53 (broad s, 4H)

10 **Example 16:**

**N-Hydroxy-5-[4-(benzenesulfonylamino)-phenyl]-4-yn-2-pentanamide (32)**



**Step 1: 4-(benzenesulfonylamino)-phenyl iodide (28)**

- Compound 28 was prepared using the procedure described in Example 15, step 1, but substituting 4-iodoaniline for 3-iodoaniline.
- Yield: 97%

$^1\text{H}$  NMR: (300 MHz,  $\text{CDCl}_3$ ): 9.15 (broad s, 1H), 7.82 (d,  $J = 8\text{Hz}$ , 2H), 7.68-7.51 (m, 5H), 7.05 (d,  $J = 8\text{Hz}$ , 2H).

5    Step 2: 4-(benzenesulfonylamino)-phenyl-propargylic alcohol (29)

Compound 29 was prepared using the procedure described in Example 15, step 2 but substituting compound 21 for compound 28.

Yield: 61%

<sup>1</sup>H NMR: (300 MHz, acetone-*d*<sub>6</sub>): 7.83-7.80 (m, 2H), 7.62-7.51 (m, 3H), 7.30 (d, J = 8Hz, 2H), 7.21 (d, J = 8Hz, 2H), 4.36 (s, 2H), 2.80 (broad s, 2H).

Step 3: 5-[4-(benzenesulfonylamino)-phenyl]-4-yn-2-pentenoate (30)

Compound 30 was prepared using the procedure described in Example 15, step 3 but substituting compound 22 for compound 29

15    Yield: 16 %

<sup>1</sup>H NMR: (300 MHz, CDCl<sub>3</sub>): 7.81-7.78 (m, 2H), 7.59-7.43 (m, 3H), 7.34 (d, J = 8Hz, 2H), 7.05 (d, J = 8Hz, 2H), 6.93 (d, J = 16Hz, 1H), 6.26 (d, J = 16Hz, 1H), 4.23 (q, J = 7Hz, 2H), 1.30 (t, J = 7Hz, 3H).

20    Step 4: 5-[4-(benzenesulfonylamino)-phenyl]-4-yn-2-pentenic acid (31)

Compound 31 was prepared using the procedure described in Example 15 step 4 but substituting compound 23 for compound 30

Yield: 92 %

<sup>1</sup>H NMR: (300 MHz, acetone-*d*<sub>6</sub>): 7.87-7.84 (m, 2H), 7.62 (m, 3H), 7.42 (d, J = 8Hz, 2H), 7.28 (d, J = 8Hz, 2H), 6.94 (d, J = 16Hz, 1H), 6.29 (d, J = 16Hz, 1H).

Step 5: N-hydroxy-5-[4-(benzenesulfonylamino)-phenyl]-4-yn-2-pentanamide (32)

Compound 32 was prepared using the procedure described in Example 15 step 6 but substituting compound 25 for compound 31

Yield: 78 %

- 5 <sup>1</sup>H NMR: (300 MHz, acetone-*d*<sub>6</sub>): 7.84 (broad s, 2H), 7.60-7.55 (m, 3H), 7.38-7.30 (m, 4H), 6.84 (d, *J* = 16Hz, 1H), 6.40 (d, *J* = 16Hz, 1H).

**Example 17:**

***N*-Hydroxy-5-[4-benzenesulfonylamino)-phenyl]-pentanamide (34)**

10

**Step 1: 5-[4-(benzenesulfonylamino)-phenyl]-pentanoic acid (33)**

Compound 33 was prepared using the procedure described in Example 15 step 5 but substituting compound 24 for compound 31.

Yield: 100 %

- 15 <sup>1</sup>H NMR: (300 MHz, acetone-*d*<sub>6</sub>): = 7.78-7.75 (m, 2H), 7.56-7.46 (m, 3H), 7.16-7.05 (m, 4H), 2.52 (broad s, 2H), 2.29-2.25 (m, 2H), 1.56 (broad s, 4H).

**Step 2: *N*-Hydroxy-5-[4-benzenesulfonylamino)-phenyl]-pentanamide (34)**

- 20 Compound 34 was prepared using the procedure described in Example 15 step 6 but substituting compound 25 for compound 33.

Yield: 62 %

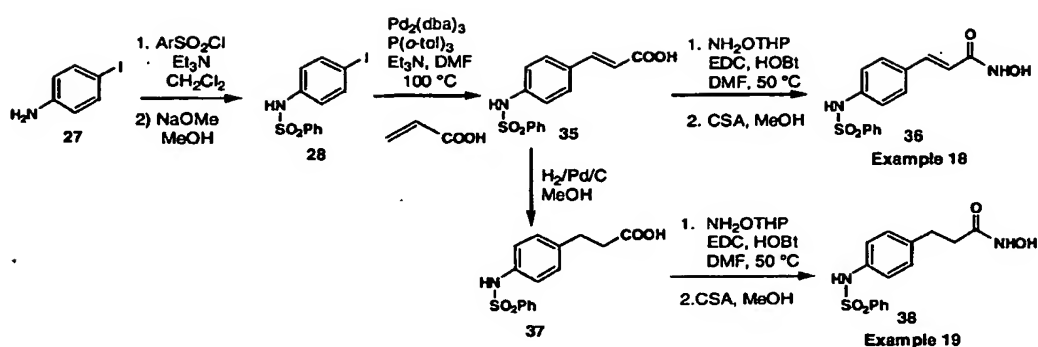
<sup>1</sup>H NMR: (300 MHz, acetone-*d*<sub>6</sub>): 7.78-7.75 (m, 2H), 7.59-7.51 (m, 3H), 7.09 (broad s, 4H), 2.85 (broad s, 1H), 2.53 (broad s, 2H), 2.05 (broad s, 2H), 1.56 (broad s, 4H).

25

**Example 18:**

***N*-Hydroxy-3-[4-(benzenesulfonylamino)-phenyl]-2-propenamide (36)**





5

### Step 1: 3-[4-(benzenesulfonylamino)-phenyl]-2-propenoic acid (35)

To a solution of 28 (500 mg, 1.39 mmol), in DMF (10 mL) at room temperature were added tris(dibenzylideneacetone)dipalladium(0) ( $\text{Pd}_2(\text{dba})_3$ ; 38 mg, 1.67 mmol), tri-*o*-tolylphosphine ( $\text{P}(\text{o-tol})_3$ , 25 mg, 0.83 mmol),  $\text{Et}_3\text{N}$  (483  $\mu\text{L}$ , 3.48 mmol) and finally acrylic acid (84  $\mu\text{L}$ , 1.67 mmol). The resulting solution was degassed and purged several times with  $\text{N}_2$ , then heated overnight at 100 °C. The solution was filtrated through a Celite pad with a fritted glass funnel then the filtrate was evaporated. The residue was purified by flash chromatography using  $\text{CH}_2\text{Cl}_2/\text{MeOH}$  (95:5) as solvent mixture yielding the title compound 35 (415 mg, 99 %) as yellowish solid.

$^1\text{H}$  NMR: (300 MHz, acetone- $d_6$ ): 7.88-7.85 (m, 2H), 7.62-7.55 (m, 6H), 7.29 (d,  $J = 9\text{ Hz}$ , 2H), 6.41 (d,  $J = 16\text{ Hz}$ , 1H), 2.95 (s, 1H), 2.79 (s, 1H).

### Step 2: N-Hydroxy-3-[4-(benzenesulfonylamino)-phenyl]-2-propenamide (36)

To a solution of 35 (200 mg, 0.660 mmol) in DMF (10 mL) at room temperature were added 1-(3-Dimethylaminopropyl)-3-ethyl-carbodiimide hydrochloride (EDCI, 151 mg, 0.79 mmol), and 1-Hydroxybenzotriazole hydrate (HOBT, 134 mg, 0.99 mmol). The mixture was stirred 20 min. at room temperature then  $\text{NH}_2\text{OTHP}$  (116 mg, 0.99 mmol) was added. The resulting mixture was heated at 50 °C for 24 h then the DMF solvent was evaporated under reduced pressure and the residue was dissolved in  $\text{CH}_2\text{Cl}_2$ , washed with a

5 saturated aqueous solution of  $\text{NaHCO}_3$ . The combined organic extracts were dried over ( $\text{MgSO}_4$ ) then condensed. The crude compound was purified by flash chromatography using Hexane/acetone (7:3) as solvent mixture. The residue was then dissolved in MeOH (10 mL) then 10-camphorsulfonic acid (CSA, 77 mg, 0.33 mmol) was added. The mixture was stirred 2 h at room temperature  
10 then the solvents were evaporated under reduced pressure at room temperature to avoid thermal decomposition. The crude product was purified by flash chromatography using  $\text{CH}_2\text{Cl}_2$ /MeOH (9:1) as solvent mixture giving compound 36 (116mg, 55%) as a orange solid.  
 $^1\text{H}$  NMR: (300 MHz, acetone- $d_6$ ): 7.85-7.83 (m, 2H), 7.64-7.47 (m, 6H), 7.26 (d, J =  
15 8Hz, 2H), 6.48 (m, 1H), 2.82 (s, 1H), 2.79 (s, 1H).

**Example 19:**

**N-Hydroxy-3-[4-(benzenesulfonylamino)-phenyl]-2-propanamide (38)**

**Step 1: 3-[4-(benzenesulfonylamino)-phenyl]-2-propionic acid (37)**

20 To a solution of 35 (350 mg, 1.16 mmol) in MeOH (15 mL) at room temperature was added a solution of Pd/C 10% (50 mg. in MeOH ~3 mL). Then the resulting solution was purged several times with  $\text{H}_2$  with a final pressure of 60 psi. The solution was stirred 4 h then filtrated through a Celite pad with a fritted glass funnel. The filtrate was evaporated and the residue compound 37  
25 was pure enough to use for the next step without further purification.  
 $^1\text{H}$  NMR: (300 MHz, acetone- $d_6$ ): 8.92 (broad s, 1H), 7.79-7.76 (m, 2H), 7.60-7.47 (m, 3H), 7.12 (s, 4H), 3.32 (s, 1H), 2.81 (t, J = 8Hz, 2H), 2.53 (t, J = 8Hz, 2H).

**Step 2: N-Hydroxy-3-[4-(benzenesulfonylamino)-phenyl]-2-propanamide (38)**

30 To a solution of 37 (1.16 mmol) in DMF (10 mL) at room temperature were added 1-(3-Dimethylaminopropyl)-3-ethyl-carbodiimide hydrochloride (EDC, 266 mg, 1.39 mmol), and 1-Hydroxybenzotriazole hydrate (HOBT, 235 mg, 1.74 mmol). The mixture was stirred 20 min. at room temperature then

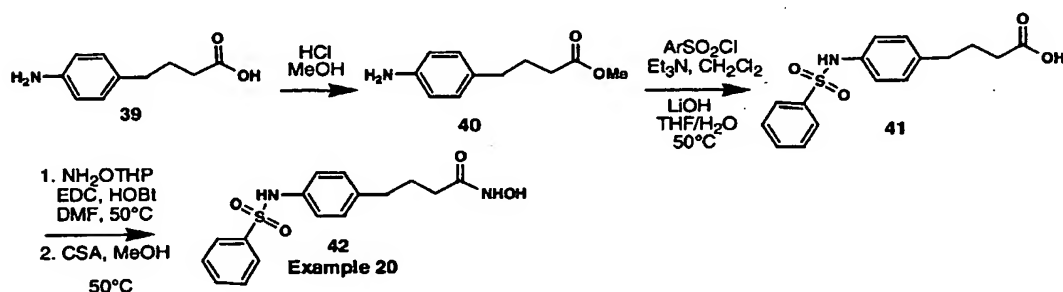
5  $\text{NH}_2\text{OTHP}$  (204 mg, 1.74 mmol) was added. The resulting mixture was heated at 50 °C for 24 h then the DMF solvent was condensed under reduced pressure and the residue was dissolved in  $\text{CH}_2\text{Cl}_2$ , washed with a saturated aqueous solution of  $\text{NaHCO}_3$ . The combined organic extracts were dried over ( $\text{MgSO}_4$ ) then evaporated. The crude compound was purified by flash chromatography using  
 10 Hexane/acetone (7:3) as solvent mixture. The residue was then dissolved in MeOH (10 mL) then 10-camphorsulfonic acid (CSA, 135 mg, 0.58 mmol) was added. The mixture was stirred 2 h at room temperature then the solvents were evaporated under reduced pressure at room temperature to avoid thermal decomposition. The crude was purified by flash chromatography using  
 15  $\text{CH}_2\text{Cl}_2/\text{MeOH}$  (9:1) as solvent mixture giving the title compound 38 (237 mg, 64 %, for the last 3 steps) as a yellow solid.

$^1\text{H}$  NMR: (300 MHz, acetone- $d_6$ ): 8.91 (broad s, 1H), 7.78-7.76 (m, 2H), 7.57-7.51 (m, 3H), 7.10 (broad s, 4H), 2.82 (broad s, 2H), 2.34 (broad s, 2H), 1.07 (s, 1H), 0.85 (s, 1H).

20

### Example 20:

#### N-Hydroxy-4-[4-(benzenesulfonylamino)-phenyl]-butanamide (42)



25

#### Step 1: Methyl-4-(4-aminophenyl)-butanoate (40)

To a solution of 4-(4-aminophenyl)-butyric acid (5g, 27.90 mmol) in MeOH (100 mL) at room temperature was added HCl conc. (37% 15 mL). The resulting mixture was stirred overnight at 50 °C then treated with a saturated

- 5 aqueous solution  $\text{NaHCO}_3$  and  $\text{Na}_2\text{CO}_3$  solid until pH 9. The solvent was evaporated under reduced pressure then the aqueous phase was extracted several times with  $\text{CH}_2\text{Cl}_2$ . The crude material was purified by flash chromatography using  $\text{CH}_2\text{Cl}_2/\text{MeOH}$  as solvent mixture yielding **40** (4.93 g, 91%) as orange solid.
- 10  $^1\text{H}$  NMR: (300 MHz, acetone- $d_6$ ): 6.89 (d,  $J = 8\text{Hz}$ , 2H), 6.59 (d,  $J = 8\text{Hz}$ , 2H), 4.40 (broad s, 1H), 3.60 (s, 3H), 2.48 (t,  $J = 7\text{ Hz}$ , 2H), 2.28 (t,  $J = 7\text{Hz}$ , 2H), 1.82 (qt,  $J = 7\text{ Hz}$ , 2H).

Step 2: 4-[4-(benzenesulfonylamino)-phenyl]-butyric acid (**41**)

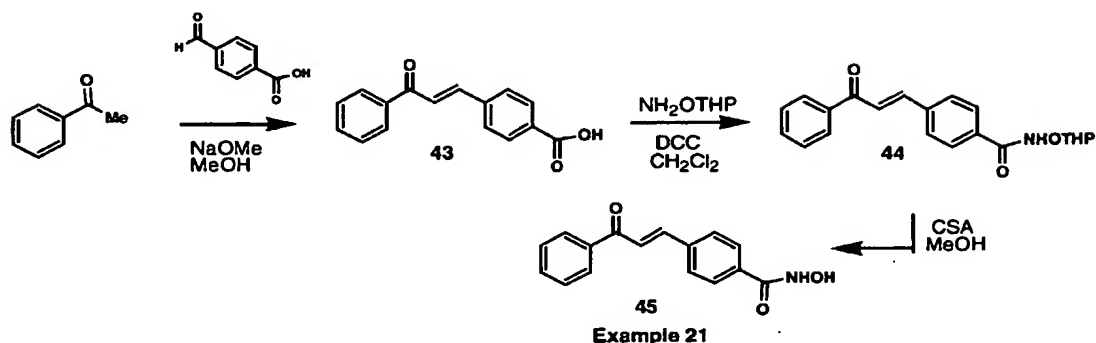
- 15 To a solution of **40** (500 mg, 2.59 mmol) in  $\text{CH}_2\text{Cl}_2$  at room temperature were added  $\text{Et}_3\text{N}$  (901  $\mu\text{L}$ , 6.48 mmol) followed by benzenesulfonyl chloride (661  $\mu\text{L}$ , 5.18 mmol). The mixture was stirred overnight at room temperature then treated with a saturated aqueous solution of  $\text{NH}_4\text{Cl}$ . The phases were separated and the organic layer was extracted several times with  $\text{CH}_2\text{Cl}_2$ . The combined
- 20 organic extracts were dried over ( $\text{MgSO}_4$ ) then evaporated under reduced pressure. The residue was dissolved in a solvent mixture of THF (25 mL) and water (25 mL) then  $\text{LiOH}$  (1.08 g, 25.9 mmol) was added. The mixture was heated at 50  $^\circ\text{C}$  for 1 h then treated with  $\text{HCl}$  (1N) until pH2. The phases were separated and the aqueous layer was extracted several times with  $\text{AcOEt}$ . The
- 25 combined organic extracts were dried over ( $\text{MgSO}_4$ ) then evaporated. The crude was purified by flash chromatography using  $\text{CH}_2\text{Cl}_2/\text{MeOH}$  (95:5) as solvent mixture yielding **41** (800 mg, 96%) as a white solid
- $^1\text{H}$  NMR: (300 MHz,  $\text{CDCl}_3$ ): 8.82 (1H, s broad), 7.77-7.74 (2H, m), 7.55-50 (1H, m), 7.44-7.39 (2H, m), 7.05-6.97 (4H, m), 2.58 (2H, t,  $J = 7\text{Hz}$ ), 2.31 (2H, t,  $J = 7\text{Hz}$ ),
- 30 2.17 (1H, s), 1.94-1.84 (2H, m).

5    Step 3: N-Hydroxy-4-[4-(benzenesulfonylamino)-phenyl]-butanamide (42)

To a solution **41** (800 mg, 2.59 mmol) in DMF (20 mL) at room temperature were added 1-(3-Dimethylaminopropyl)-3-ethyl-carbodiimide hydrochloride (EDC, 593 mg, 3.12 mmol), and 1-Hydroxybenzotriazole hydrate (HOBT, 524 mg, 3.89 mmol). The mixture was stirred 20 min. at room temperature then  $\text{NH}_4\text{OTHP}$  (455 mg, 3.89 mmol) was added. The resulting mixture was heated at 50 °C for 24 h then the DMF solvent was evaporated under reduced pressure and the residue was dissolved in  $\text{CH}_2\text{Cl}_2$ , washed with a saturated aqueous solution of  $\text{NaHCO}_3$ . The combined organic extracts were dried over ( $\text{MgSO}_4$ ) then evaporated. The crude compound was purified by flash chromatography using Hexane/acetone (7:3) as solvent mixture. The residue was then dissolved in MeOH (30 mL) then 10-camphorsulfonic acid (CSA, 300 mg, 1.30 mmol) was added. The mixture was stirred 2 h at 50° C then the solvents were condensed under reduced pressure at room temperature to avoid thermal decomposition. The crude was purified by flash chromatography using  $\text{CH}_2\text{Cl}_2$ /MeOH (9:1) as solvent mixture giving the title compound **42** (115 mg, 13%) as a yellowish solid.

$^1\text{H}$  NMR: (300 MHz,  $\text{CDCl}_3$ ): 7.79-7.76 (m, 2H), 7.61-7.48 (m, 3H), 7.13-7.05 (m, 4H), 2.83 (broad s, 1H), 2.53 (t,  $J = 7\text{Hz}$ , 2H), 2.14-2.04 (m, 2H), 1.83 (t,  $J = 7\text{Hz}$ , 2H).

25

5 **Example 21:****N-Hydroxy-4-(3-oxo-3-phenylpropenyl)-benzamide (45)****Step 1: 4-(3-oxo-3-phenylpropenyl)-benzoic acid (43)**

Sodium methoxide (1.8g, 33.3 mmol) was added to a stirred suspension of 4-carboxybenzaldehyde (2.5g, 16.6 mmol) and acetophenone (2.0g, 16.6 mmol) in methanol (50 mL) at room temperature. The mixture was stirred at room temperature for 16 hours, and half of the volume of methanol was removed under reduced pressure. The mixture was poured into HCl 1M (50 mL) (until pH=2) and ethyl acetate was added. The separated aqueous layer was extracted with ethyl acetate (3x30 mL) dried (MgSO<sub>4</sub>, anh.), filtered and evaporated. The residue was triturated with dichloromethane-hexanes (1:1) to afford 3g of **43** (72% yield).

<sup>1</sup>H NMR (300 MHz, CDCl<sub>3</sub>); δ 7.50-7.87 (m, 7H), 8.04 (d, 2H, *J*=8Hz), 8.16 (d, 2H, *J*=8Hz)

**Step 2: 4-(3-oxo-3-phenylpropenyl)-N-(O-tetrahydropyranyl)-benzamide (44)**

The carboxylic acid **43** (260mg, 1.0 mmol) was dissolved in anhydrous CH<sub>2</sub>Cl<sub>2</sub> (10 mL) and DCC (256 mg, 1.2 mmol) followed by NH<sub>2</sub>OTHP (145 mg, 1.2 mmol) were added. The mixture was allowed to stir at room temperature for 2h. Added NH<sub>4</sub>Cl sat. and extracted with EtOAc. The organic layer was dried over MgSO<sub>4</sub>, filtered and the solvent was evaporated under vacuum. (Purification by

- 5 column chromatography using 1% MeOH/CH<sub>2</sub>Cl<sub>2</sub>, give the title compound which was used directly in the next step.

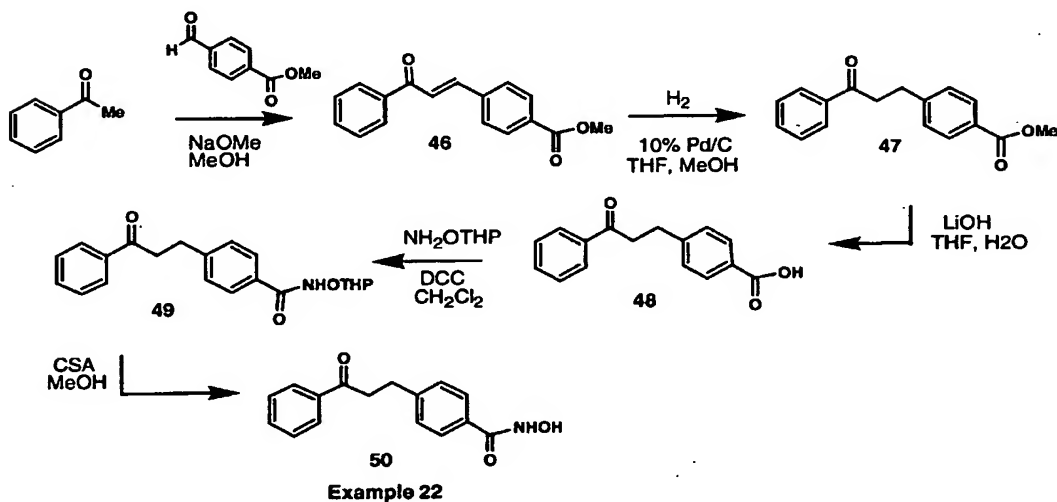
**Step 3: N-Hydroxy-4-(3-oxo-3-phenylpropenyl)-benzamide (45)**

- The protected hydroxamic acid **44** (234 mg, 0.67 mmol) was dissolved in MeOH (7mL) then CSA (31 mg, 0.13 mmol) was added. The mixture was allowed to stir at reflux for 2 hours or until the reaction was complete by TLC. Added HCl 1N, extracted with EtOAc, dried the organic layer over anhydrous MgSO<sub>4</sub> and filtered. The solvent was evaporated under vacuum. Purification by column chromatography using 5% MeOH/CH<sub>2</sub>Cl<sub>2</sub>, gave the title compound.
- 15 <sup>1</sup>H NMR (300 MHz, DMSO-*d*<sub>6</sub>), δ 7.53-8.20 (m, 11H); 9.12 (br. s, 1H); 11.35 (br. s, 1H)

**Example 22:**

**N-Hydroxy-4-(3-oxo-3-phenylpropyl)-benzamide (50)**

20



5 Step 1: Methyl-4-(3-oxo-3-phenylpropenyl)-benzoate (46)

To 4-carbomethoxybenzaldehyde (79 mg, 0.48 mmol) and acetophenone (56  $\mu$ L, 0.48 mmol) in anhydrous methanol (1.6 mL), was added neat sodium methoxide (26 mg, 0.48 mmol). The mixture was stirred at room temperature overnight then heated to reflux for 1 hour, cooled down to room temperature  
10 and added HCl 1N and EtOAc. The layers were separated and the organic layer dried over anhydrous  $\text{MgSO}_4$  and filtered. The solvent was evaporated under vacuum to afford a yellow solid, which was recrystallized from acetonitrile/water to give a pale yellow crystalline solid.

$^1\text{H}$  NMR (300 MHz,  $\text{CDCl}_3$ );  $\delta$  3.95 (s, 3H), 7.50-8.12 (m, 11H)

15

Step 2: Methyl-4-(3-oxo-3-phenylpropyl)-benzoate (47)

The aromatic enone **46** (321 mg, 1.20 mmol) was dissolved in anhydrous THF (6 mL) and anhydrous MeOH (6 mL). Added 2 small scoops of Pd 10% on activated C, placed under an atmosphere of hydrogen and allowed to stir for 2  
20 hours at room temperature. Purged with nitrogen, filtered through Celite and removed solvent by evaporation under vacuum. The benzylic alcohol is reoxidized to the ketone by the following procedure. The crude was taken back in anhydrous  $\text{CH}_2\text{Cl}_2$  (10 mL), with 3Å molecular sieves, TPAP (1 scoop) was added followed by NMO (212 mg, 1.8 mmol). Stirred at room temperature for  
25 30 minutes and filtered through a plug of silica gel. Solvent was evaporated under vacuum and purified by column chromatography using 10% EtOAc/Hexane.

$^1\text{H}$  NMR (300 MHz,  $\text{CDCl}_3$ );  $\delta$  3.14 (t, 2H), 3.34 (t, 2H), 3.90 (s, 3H), 7.30-7.60 (m, 6H), 7.92-7.99 (m, 4H).

30

Step 3: 4-(3-oxo-3-phenylpropyl)-benzoic acid (48)

To a solution of methyl ester **47** (195 mg, 0.73 mmol) in water/THF (1:1, 0.07M) was added LiOH (46 mg, 1.1 mmol). The resulting solution was stirred



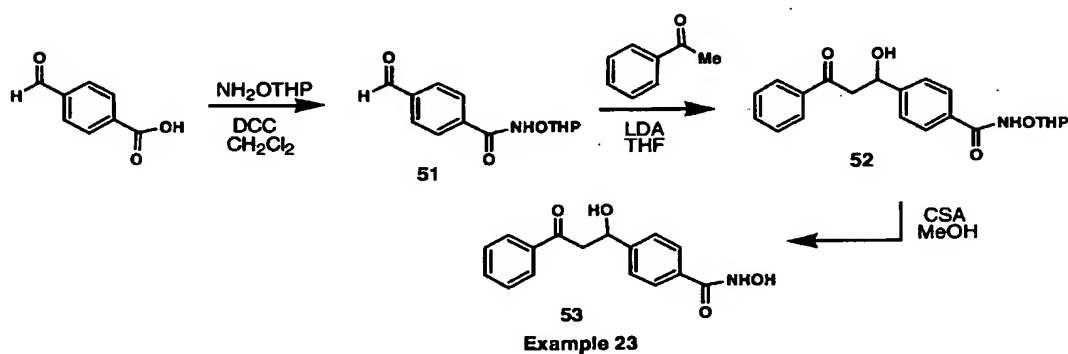
- 5 overnight at room temperature or until no starting material was detected by TLC. HCl 1N was added and the solution was extracted with EtOAc and the organic layer was dried over anhydrous  $\text{MgSO}_4$ . Filtration and evaporation of the solvent under vacuum followed by purification by column chromatography using 10% MeOH/ $\text{CH}_2\text{Cl}_2$ , gave the title compound.
- 10  $^1\text{H}$  NMR (300 MHz,  $\text{CDCl}_3$ );  $\delta$  3.16 (t, 2H), 3.36 (t, 2H), 7.33-7.60 (m, 5H), 7.93-8.06 (m, 4H).

**Step 4: N-hydroxy-4-(3-oxo-3-phenylpropyl)- benzamide (50)**

- Following the procedure described in Example 21, Steps 2-3, but
- 15 substituting compound 48 for carboxylic acid 4, the title compound was obtained.
- $^1\text{H}$  NMR (300 MHz,  $\text{DMSO}-d_6$ );  $\delta$  2.97 (t, 2H), 3.38 (t, 2H), 7.34 (d, 2H,  $J=8\text{Hz}$ ), 7.45-7.70 (m, 5H), 7.96 (dd, 2H,  $J=8\text{Hz}$ , 1Hz), 11.14 (br. s, 1H)

20 **Example 23:**

**N-Hydroxy-4-(3-oxo-3-phenyl-1-hydroxypropyl)-benzamide (53)**



**Step 1: 4-Carboxy-N-(O-tetrahydropyranyl)-benzamide (51)**

- 25 Hydroxylamine-O-THP (3.9 g, 33.2 mmol) was added to a suspension of 4-formylbenzoic acid (4.2 g, 27.7 mmol) and DCC (6.8g, 33.2 mmol) in dichloromethane (200mL). The mixture was stirred at room temperature

- 5 overnight and quenched with saturated ammonium chloride. The separated aqueous layer was extracted with ethyl acetate (3 x 100ml) and the combined organic layers were washed with brine, dried (MgSO<sub>4</sub>, anh), filtered and evaporated. Flash chromatography of the residue (10% methanol in CH<sub>2</sub>Cl<sub>2</sub>), afforded (51).
- 10 <sup>1</sup>H NMR (300 MHz, CDCl<sub>3</sub>); δ ppm. 10.04 (s, 1H), 8.95 (s, 1H), 7.99 (d, 2H, J=7.0 Hz), 7.93 (d, 2H, J=7.0 Hz), 5.1 (s, 1H), 3.60 (m, 2H), 1.60 (m, 6H)

Step 2: 4-(3-oxo-3-phenyl-1-hydroxypropyl)-N-(O-tetrahydropyranyl)-benzamide (52)

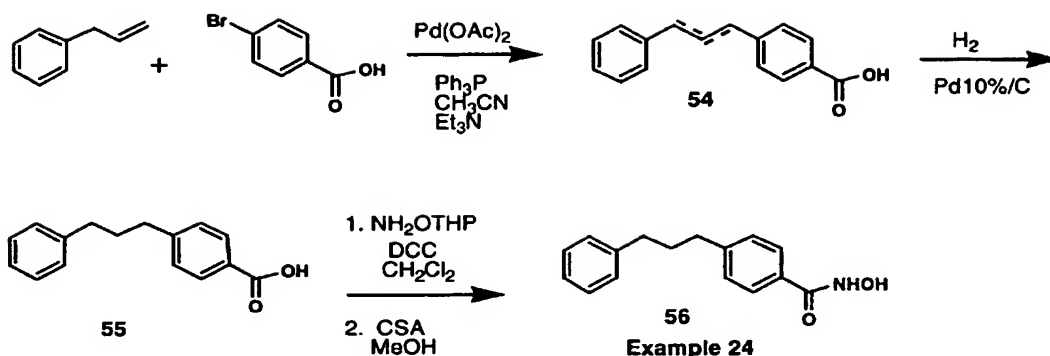
- 15 *n*-BuLi (1.4M/hexane, 1.6 mL, 2.2 mmol) was added to a 0 °C solution of diisopropylamine (337 μL, 2.4 mmol) in anhydrous THF (15mL). Stirred at 0°C 10 minutes, then cooled to -78°C. Added acetophenone, then stirred 30 minutes at -78°C. Cannulated into a -78°C solution of the aldehyde 9 (50 mg, 2.0 mmol) in anhydrous THF (10 mL). Stirred 3 hours at -78°C, then added NH<sub>4</sub>Cl.
- 20 Warmed to room temperature, extracted with EtOAc, dried over MgSO<sub>4</sub>, filtered and evaporated solvent under vacuum. Purification by HPLC CH<sub>3</sub>CN: H<sub>2</sub>O: TFA 0.1%; 10-95% gave the title compound 52.

Step 3: N-Hydroxy-4-(3-oxo-3-phenyl-1-hydroxypropyl)- benzamide (53)

- 25 Following the same procedure as described in Example 21, Step 3, but substituting compound 52 for compound 44, the title compound was obtained. <sup>1</sup>H NMR (300 MHz, DMSO-*d*<sub>6</sub>); δ 3.20 (dd, 1H, J=4Hz, J=16Hz), 3.42 (dd, 1H=16Hz, 8Hz), 5.20 (m, 1H), 7.44-8.18 (m, 9H), 11.15 (br. s, 1H), 11.32 (br. s, 1H)

30 Example 24:

N-Hydroxy-4-(3-phenylpropyl)-benzamide (56)



Step 1: 4-(3-phenylpropenyl)-benzoic acid / 4-(3-phenyl-2-propenyl)-benzoic acid (54)

Allylbenzene (255  $\mu$ L, 1.9 mmol), 4-bromobenzoic acid (523 mg, 2.6 mmol),  $\text{Et}_3\text{N}$  (0.91 mL, 6.5 mmol), Palladium (II) Acetate (16 mg, 0.052 mmol), triphenylphosphine (60 mg, 0.21 mmol) and acetonitrile (5mL) were stirred at reflux overnight in a round bottom flask. Added HCl 1N, extracted with EtOAc, dried the organic layer on anhydrous  $\text{MgSO}_4$ , filtered, evaporated solvent under vacuum. Purified by column chromatography using 10% MeOH /  $\text{CH}_2\text{Cl}_2$  yielded 90 mg (14%) of mixture of two regioisomers 54. The mixture was then submitted for hydrogenation without further characterization.

Step 2: 4-(3-phenylpropyl)-benzoic acid (55)

A mixture of regioisomeric olefins 54 (100mg, 0.42 mmol) and Pd 10% on C (10mg) in methanol (4mL) was vigorously stirred under  $\text{H}_2$  atmosphere (14 psi). The mixture was stirred for 2 hours at room temperature, filtered through Celite and evaporated to afford 55 as an oil. Flash chromatography of the residue gave 55 (88 mg, 88%).

$^1\text{H}$  NMR (300 MHz,  $\text{CDCl}_3$ );  $\delta$  ppm 8.10 (d, 2H,  $J=8.0$  Hz), 7.35 (m, 7H), 2.73 (m, 4H), 2.00 (m, 2H)

5 Step 3: N-Hydroxy-4-(3-phenylpropyl)-benzamide (56)

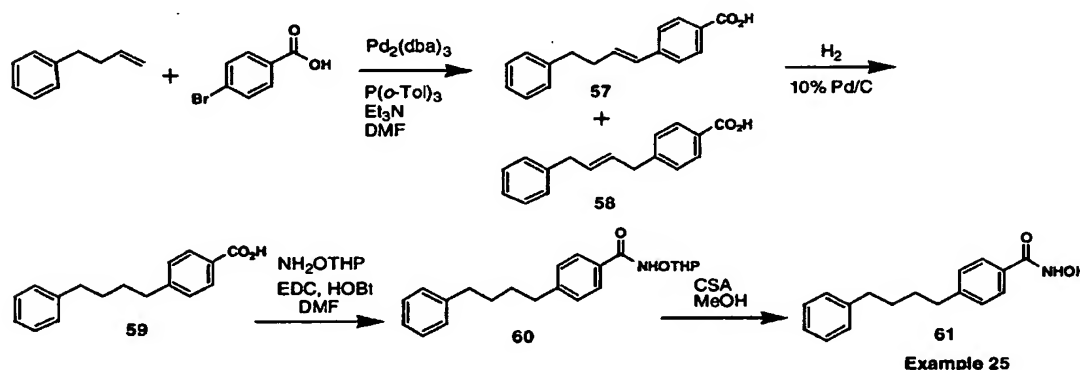
Following the same procedure as described in Example 21, Steps 2-3, but substituting compound 55 for compound 43, the title compound was obtained as a beige solid. (24 mg, 26% yield)

<sup>1</sup>H NMR (300 MHz, CD<sub>3</sub>OD); δ (ppm) 7.63 (d, 2H, J=8.0 Hz); 7.38-7.05 (m, 7H),

10 2.63 (m, 4H), 1.91 (m, 2H)

Example 25:

N-Hydroxy-4-(4-phenylbutyl)-benzamide (61)



Step 1: 4-(1-butenyl-4-phenyl)-benzoic acid / 4-(2-butenyl-4-phenyl)-benzoic acid (57/58)

Under nitrogen atmosphere in a 25 mL round bottomed flask were mixed:

20 4-phenyl-1-butene (568 μL, 3.8 mmol), 4-bromobenzoic acid (634 mg, 3.2 mmol), tris(dibenzylideneacetone)dipalladium(0) (87 mg, 0.1 mmol), tri-*o*-tolylphosphine (58 mg, 0.2 mmol), triethylamine (1.1 mL, 7.9 mmol) in *N,N*-dimethylformamide (7 mL, 0.5 M solution). The mixture was stirred for 22 hours at 100°C. Then, the resulting suspension was cooled to room temperature,

25 filtered through Celite and rinsed with ethyl acetate. The filtrate was acidified with 1N HCl, the phases were separated and the aqueous layer was extracted with ethyl acetate. The combined organic layers were washed with water, brine,

5 dried over  $\text{MgSO}_4$ , filtered and concentrated. The resulting solid was triturated with hexane : dichloromethane (9:1) to give 367 mg (46%) of beige solid 57/58.  $^1\text{H}$  NMR (300 MHz,  $(\text{CD}_3)_2\text{CO}$ ):  $\delta$  (ppm) 2.50-2.60 (m, 2H), 2.80 (t, 2H,  $J = 9.0$  Hz), 6.40-6.50 (m, 2H), 7.12-7.35 (m, 5H), 7.41 (d, 2H,  $J = 9.0$  Hz), 7.92 (d, 2H,  $J = 9.0$  Hz).

10

Step 2: 4-(4-phenylbutyl)-benzoic acid (59)

Following the procedure described in Example 24, Step 2, but substituting compound 57/58 for compounds 54, the title compound was obtained as a white solid in 92% yield.

15  $^1\text{H}$  NMR (300 MHz,  $\text{CD}_3\text{OD}$ );  $\delta$  (ppm) 1.60-1.75 (m, 4H), 2.65 (t, 2H,  $J=9.0$  Hz), 2.72 (t, 2H,  $J=9.0$  Hz), 7.12-7.30 (m, 5H), 7.33 (d, 2H,  $J=9.0\text{Hz}$ ), 7.96 (d, 2H,  $J=9.0\text{Hz}$ )

Step 3: 4-(4-phenylbutyl)-N-(O-tetrahydropyranyl)-benzamide (60)

20 Under nitrogen atmosphere in a 25 mL round bottomed flask, to 4-(4-phenylbutyl)benzoic acid 59 (341 mg, 1.3 mmol) in 5 mL of N,N-dimethylformamide (0.3 M solution) was added the 1-(3-dimethylaminopropyl)-3-ethylcarbodiimide hydrochloride (308 mg, 1.6 mmol) and the 1-hydroxybenzotriazole hydrate (272 mg, 2.0 mmol) at room temperature. The mixture was stirred for 30 minutes then, the 2-(tetrahydropyranyl) hydroxylamine (235 mg, 2.0 mmol) was added and the mixture was stirred for 4 days. The N,N-dimethylformamide was removed under vacuum, the resulting oil was dissolved in ethyl acetate, washed with water and brine, dried over  $\text{MgSO}_4$ , filtered and concentrated to give 95% yield of crude title compound 60.

25  $^1\text{H}$  NMR (300 MHz,  $\text{CD}_3\text{OD}$ );  $\delta$  (ppm) 1.50-1.75 (m, 10H), 2.65 (t, 2H,  $J=9.0$  Hz), 2.72 (t, 2H,  $J=9.0\text{Hz}$ ), 3.51 (d, 1H,  $J=15\text{Hz}$ ), 4.05 (t, 1H,  $J=15\text{Hz}$ ), 5.05 (s, 1H), 7.10-7.35 (m, 7H), 7.75 (d, 2H,  $J=9.0\text{Hz}$ ), 10.60 (s, 1H)

30

5    Step 4: N-Hydroxy-4-(4-phenylbutyl)-benzamide (61)

Under nitrogen atmosphere, to the crude oil in a 25 mL round bottomed flask, were added 5 mL of methyl alcohol (0.3 M solution) and camphorsulfonic acid (333 mg, 1.4 mmol). The mixture was stirred for 2 hours at room temperature. The methyl alcohol was removed under vacuum without heating and the resulting oil was purified by flash chromatography eluting methyl alcohol and dichloromethane (1 : 19). The solid was with hexane : dichloromethane (9:1) to give 212 mg (59 %) of beige solid **61**.  
<sup>1</sup>H NMR (300 MHz, (CD<sub>3</sub>)<sub>2</sub>CO): δ 1.66 (m, 4H), 2.65 (t, 2H, J = 7.2 Hz), 2.70 (t, 2H, J = 7.1 Hz), 7.15-7.31 (m, 7H), 7.75 (d, 2H, J = 7.8 Hz), 8.18 (broad s, 1H), 10.68 (broad s, 1H).  
<sup>13</sup>C NMR (75.46 MHz, (CD<sub>3</sub>)<sub>2</sub>CO): δ 31.6 (t), 31.8 (t), 36.1 (t), 36.2 (t), 2 X 126.4 (d), 127.8 (d), 2 X 129.1 (d), 2 X 129.2 (d), 2 X 129.3 (d), 130.6 (s), 143.3 (s), 147.3 (s), 165.9 (s).

10  
1520    Example 26:N-Hydroxy-3-(3-phenylpropyl)-benzamide (64)Step 1: 3-(3-phenylpropenyl)-benzoic acid (62)

Following the same procedure as described in Example 24, step 1, but substituting 4-bromobenzoic acid for 3-bromobenzoic acid, the title compound was obtained as mixture of olefins. The mixture was submitted to the next step without purification.

25  
<sup>1</sup>H NMR (300 MHz, CDCl<sub>3</sub>): δ (ppm); 3.6 (dd, 2H, CH<sub>2</sub>); 6.4 (dd, 2H, vinylic); 7.0-7.5 (m, 8H, CHAr); 8.0 (s, 1H, CHAr)

5 Step 2: 3-(3-phenylpropyl)-benzoic acid (63)

Following the same procedure as described in Example 24, Step 2, but substituting compound 62 for compound 54, the title compound was obtained in 52% yield and submitted to the next step without further purification.

<sup>1</sup>H NMR (300 MHz, CDCl<sub>3</sub>); δ (ppm); 2.0 (m, 2H, CH<sub>2</sub>); 2.7 (m, 4H, 2CH<sub>2</sub>); 7.0-7.4 (m, 8H, CHAr); 8.0 (s, 1H, CHAr)

Step 3: N-Hydroxy-3-(3-phenylpropyl)-benzamide (64)

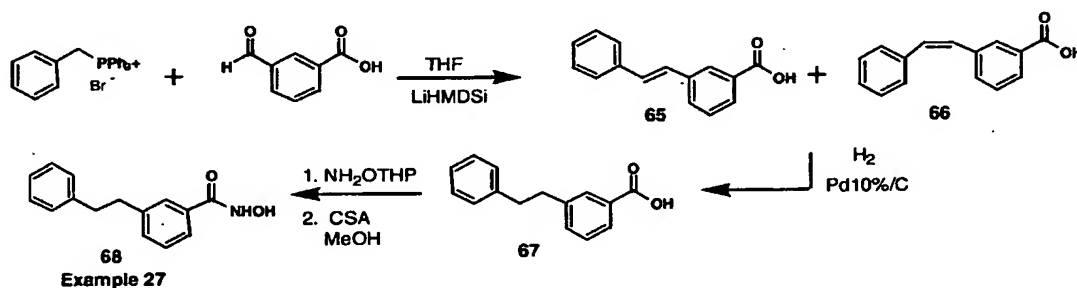
Following the procedure described in Example 25, Step 3-4, but substituting compound 63 for compound 59, the title compound was obtained.

15 Purification by flash chromatography using CH<sub>2</sub>Cl<sub>2</sub>: MeOH (9.5:0.5) gave compound 64 in 20% yield.

<sup>1</sup>H NMR (300 MHz, DMSO-*d*<sub>6</sub>); δ 1.8 (m, 2H, CH<sub>2</sub>); 2.8 (m, 4H, CH<sub>2</sub>); 7.0-7.4 (m, 7H, CHAr); 7.6 (s, CHAr); 9.0 (s, NH); 11.2 (s, OH)

20 Example 27:

N-Hydroxy-3-(2-phenylethyl)-benzamide (68)



Step 1: 3-(2-phenylethenyl)-benzoic acid (65/66)

25 A 1.0 M solution of lithium bis(trimethylsilyl) amide (3.3 mL, 3.3 mmol) in THF was added to a stirred suspension of benzyltriphenylphosphonium bromide (1.44 g, 3.6 mmol) in THF (35mL) at 0°C. The resulting orange solution was added via cannula to a mixture of 3-carboxybenzaldehyde (500 mg, 3.3

- 5 mmol) and lithium bis(trimethylsilyl)amide (3.3 mL, 3.3 mmol) in THF (10mL). The mixture was stirred overnight at room temperature. A 1N solution of HCl (75 mL) and ethyl acetate (75 mL) were added and the separated aqueous layer was extracted with ethyl acetate (3x50 mL), dried (MgSO<sub>4</sub>, anh.) filtered and evaporated. The residue was purified by HPLC (10:95 CH<sub>3</sub>CN: H<sub>2</sub>O, TFA 0.1%)  
10 to afford 130 mg of the title compound (17%)  
'H NMR (300 MHz, CDCl<sub>3</sub>); δ (ppm) (1:1) E:Z mixture 8.22 (s, 1H), 7.98 (s, 1H), 7.90-7.10 (m, 16H), 6.70 (d, 1H, J=15.0 Hz), 6.62 (d, 1H, J=15.0 Hz)

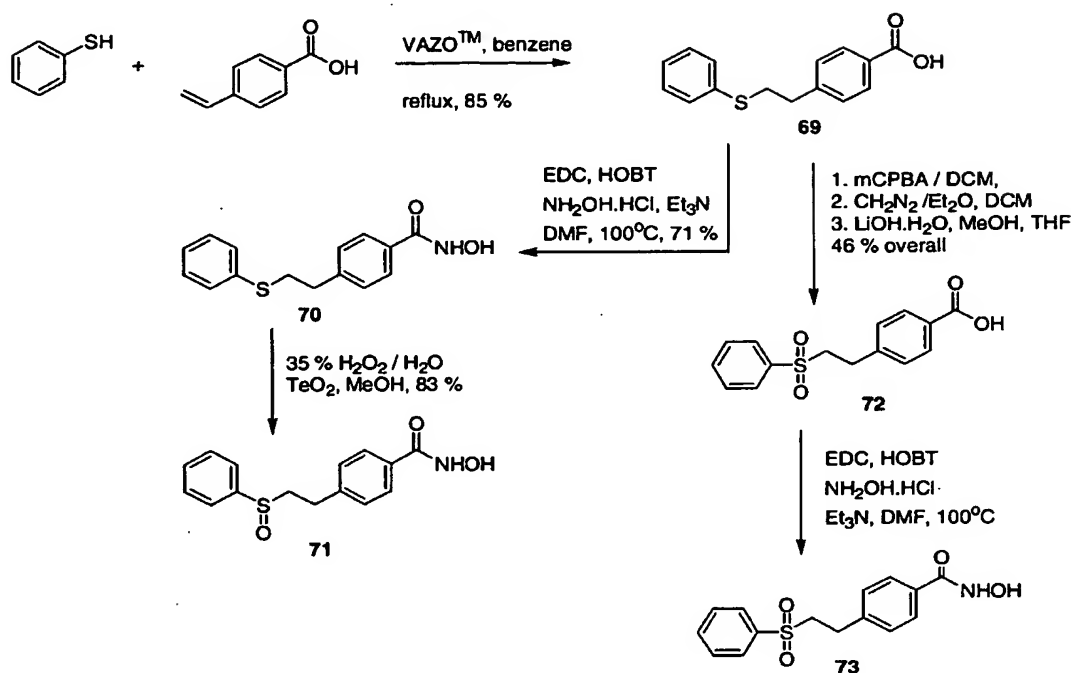
Step 2: 3-(2-phenylethyl)-benzoic acid (67)

- 15 Following the same procedure as described in Example 24, Step 2, but substituting compounds 65/66 for compound 54, the title compound was obtained quantitatively.  
'H NMR (300 MHz, CDCl<sub>3</sub>); δ (ppm) 2.98 (m, 4H); 7.30 (m, 7H); 7.99 (m, 2H)

20 Step 3: N-Hydroxy-3-(2-phenylethyl)-benzamide (68)

- Following the same procedure as described in Example 25, Step 3 and 4, but substituting compound 67 for compound 59, the title compound was obtained in 22% yield.  
'H NMR (300 MHz, DMSO-*d*<sub>6</sub>); δ (ppm) 2.82 (s, 4H); 7.03-7.08 (m, 8H); 7.62 (s, 1H); 8.98 (br. s, 1H); 11.15 (br. s, 1H)  
25



5 **Example 28:****N-Hydroxy-4-(2-thiophenyl)-ethyl benzoamide (70)****Step 1: 4-(2-thiophenyl)-ethyl benzoic acid (69)**

- 10 According to the published procedure (Gareau *et al.*, *Tet. Lett.*, **1994**, 1837), under nitrogen atmosphere in a 50 mL round bottomed flask containing 4-vinylbenzoic acid (1.0 g, 6.75 mmoles) in 10 mL of benzene (0.7 M) was added benzenethiol (797  $\mu$ L, 7.76 mmoles) followed by VAZO™ (Aldrich Chemical Company, 495 mg, 2.02 mmoles). The mixture was stirred for 12 hours at reflux.
- 15 The resulting solution was cooled at room temperature and the solvent was evaporated under vacuo. The solid was purified by trituration using hexane and dichloromethane to afford 1.94 g (85 %) of white solid.

<sup>1</sup>H NMR (300 MHz, CDCl<sub>3</sub>):  $\delta$  3.01 (t, 2H, J = 8.4 Hz), 3.28 (dd, 2H, J = 7.2, 7.8 Hz), 7.21 (tt, 1H, J = 1.2, 7.2 Hz), 7.34 (t, 2H, J = 8.1 Hz), 7.38-7.43 (m, 1H), 7.41 (d, 2H, J = 8.4 Hz), 7.97 (d, 2H, J = 8.1 Hz).

20

5 Step 2: N-Hydroxy-4-(2-thiophenyl)-ethyl benzamide (70)

Under nitrogen atmosphere in a 50 mL round bottomed flask containing 4-(2-thiophenyl)-ethyl benzoic acid (600 mg, 2.32 mmol) in 12 mL of N,N-dimethylformamide (0.2 M) was added 1-(3-dimethylaminopropyl)-3-ethylcarbodiimide hydrochloride (579 mg, 3.02 mmol) and 1-hydroxy-benzotriazole hydrate (377 mg, 2.79 mmol) at room temperature. The mixture was stirred 30 minutes then, hydroxylamine hydrochloride (242 mg, 3.48 mmol) and triethylamine (971  $\mu$ L, 6.97 mmol) was added and the mixture was stirred for 12 hours at 50°C. The N,N-dimethylformamide was removed under vacuo and the resulting oil was dissolved in ethyl acetate, washed with water, saturated sodium hydrogen carbonate solution, water and brine. The organic layer was dried over anhydrous magnesium sulfate, filtered and concentrated under vacuo. The crude solid was purified by trituration using hexane and dichloromethane to afford 450 mg (71 %) of a beige solid. RP-HPLC (Hewlett-Packard 1100, column C18 HP 4.6x250mm, flow 1 mL/min, 10-95 % CH<sub>3</sub>CN / H<sub>2</sub>O in 42 min with 0.1 % TFA); Purity: 95.8 % (220 nm), 93.2 % (254 nm).

<sup>1</sup>H NMR (300.072 MHz, (CD<sub>3</sub>)<sub>2</sub>CO):  $\delta$  2.98 (t, 2H, J = 7.2 Hz), 3.26 (dd, 2H, J = 6.6, 8.4 Hz), 7.21 (tt, 1H, J = 1.5, 6.9 Hz), 7.31-7.42 (m, 6H), 7.77 (d, 2H, J = 9.3 Hz), 8.08 (broad s, 1H), 10.69 (broad s, 1H).

25 <sup>13</sup>C NMR (75.46 MHz, (CD<sub>3</sub>)<sub>2</sub>CO):  $\delta$  34.8 (t), 35.9 (t), 126.7 (d), 127.9 (d), 2 X 129.6 (d), 2 X 129.7 (d), 2 X 129.9 (d), 131.3 (s), 137.3 (s), 145.0 (s).

Elemental Analysis; Calc for C<sub>15</sub>H<sub>15</sub>O<sub>2</sub>NS x 0.1 H<sub>2</sub>O: % C = 75.31, % H = 7.14, % N = 5.17. Found: % C = 75.2  $\pm$  0.1, % H = 7.41  $\pm$  0.07, % N = 5.17  $\pm$  0.01.

30 N-Hydroxy-4-(2-benzenesulfonyl)-ethyl benzamide (73)Step 1: 4-(2-benzenesulfonyl)-ethyl benzoic acid (72)

Under nitrogen atmosphere in a 100 mL round bottomed flask containing 4-(2-thiophenyl)-ethyl benzoic acid (69) (600 mg, 2.32 mmol) in 20 mL of

5 dichloromethane (0.1 M) at 0° C was added portionwise 3-chloroperbenzoic acid (Aldrich Chemical Co., 57-86 % pure solid by, 2 g, 6.97 mmol), as described by Nicolaou *et al.*, *J. Am. Chem. Soc.*, **114**: 8897 (1992). The mixture was allowed to reach room temperature and was stirred for 1 hour. Dimethyl sulfide (5 mL) was added, the mixture was diluted in dichloromethane and washed 3 times with  
10 water. The organic layer was dried over anhydrous magnesium sulfate, filtered and the solvent were evaporated in vacuo to afford 3 g of white solid. This mixture of 3-chlorobenzoic acid and the desired 4-(2-benzenesulfonyl)-ethyl benzoic acid was placed in a 125 mL Erlenmeyer flask, dissolved in 30 mL of dichloromethane and treated with an excess of freshly prepared diazomethane  
15 solution in diethyl ether (0.35 M). Nitrogen was bubbled to removed the excess of diazomethane and solvents were evaporated under vacuum. The resulting solid was purified by flash chromatography, eluting with 20 % ethyl acetate : 80 % hexane to afford 341.6 mg (48 %) of the corresponding ester. Saponification of this ester was done using the same procedure as described in Example 1, step 2,  
20 to afford 312.4 mg (96 %) of 4-(2-benzenesulfonyl)-ethyl benzoic acid (72)  
<sup>1</sup>H NMR (300 MHz, CDCl<sub>3</sub>): δ 3.06-3.11 (m, 2H), 3.56-3.61 (m, 2H), 7.37 (d, 2H, J = 8.4 Hz), 7.67 (tt, 2H, J = 1.5, 7.2 Hz), 7.76 (tt, 1H, J = 1.2, 7.5 Hz), 7.93 (d, 2H, J = 8.7 Hz), 7.97 (dd, 2H, J = 1.8, 6.9 Hz).

25 Step 2: N-Hydroxy-4-(2-benzenesulfonyl)-ethyl benzamide (73)

Following the procedure described for N-hydroxy-4-(2-thiophenyl)-ethyl benzamide, but substituting 4-(2-benzenesulfonyl)-ethyl benzoic acid for 4-(2-thiophenyl)-ethyl benzoic acid, the title compound was obtained as a beige solid. RP-HPLC (Hewlett-Packard 1100, column C18 HP 4.6x250mm, flow 1 mL/min,  
30 10-95 % CH<sub>3</sub>CN / H<sub>2</sub>O in 42 min with 0.1 % TFA); Purity: 98.8 % (220 nm), 97.6 % (254 nm).

<sup>1</sup>H NMR (300.072 MHz, (CD<sub>3</sub>)<sub>2</sub>CO): δ 2.98 (t, 2H, J = 7.2 Hz), 3.26 (dd, 2H, J = 6.6, 8.4 Hz), 7.21 (tt, 1H, J = 1.5, 6.9 Hz), 7.31-7.42 (m, 6H), 7.77 (d, 2H, J = 9.3 Hz), 8.08 (broad s, 1H), 10.69 (broad s, 1H).

- 5  $^{13}\text{C}$  NMR (75.46 MHz,  $(\text{CD}_3)_2\text{CO}$ ):  $\delta$  25.2 (t), 34.3 (t), 55.6 (t), 128.0 (d), 2 X 128.8 (d), 129.4 (d), 2 X 130.2 (d), 131.1 (s), 134.5 (d), 140.7 (s), 145.5 (s), 165.8 (s).

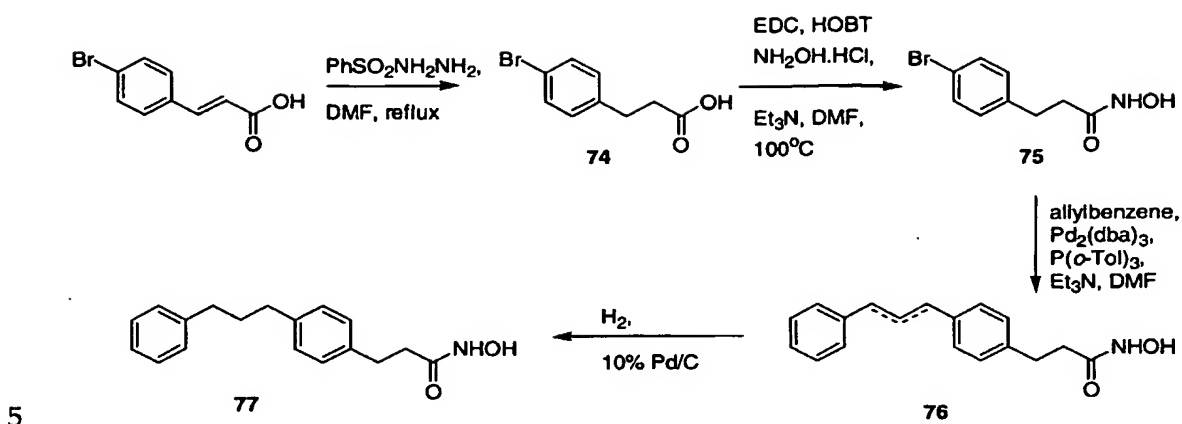
**N-Hydroxy-4-(2-benzenesulfoxide)-ethyl benzamide (71)**

- According to the procedure described by Van Der Borcht *et al.*, *J. Org. Chem.*, 65: 288 (2000), under anitrogen atmosphere in a 10 mL round bottomed flask containing N-hydroxy-4-(2-thiophenyl)-ethyl benzamide (70) (50 mg, 0.18 mmol) in 2 mL of methanol (0.1 M) was added tellurium dioxide (3 mg, 0.018 mmol) followed by a solution 35 % in water of hydrogen peroxide (32  $\mu\text{L}$ , 0.36 mmol). The mixture was stirred for five days and then brine was added. The aqueous layer was extracted 3 times with ethyl acetate and the combined organic layers were dried over anhydrous magnesium sulfate, filtered and the solvent were evaporated under vacuo. The resulting solid (43.3 mg) was purified by trituration using acetonitrile to afford 10 mg (20 %) of beige solid.
- 10 RP-HPLC (Hewlett-Packard 1100, column C18 HP 4.6x250mm, flow 1 mL/min, 10-95 %  $\text{CH}_3\text{CN}$  /  $\text{H}_2\text{O}$  in 42 min with 0.1 % TFA); Purity: 98.8 % (220 nm), 97.9 % (254 nm).
- 15  $^1\text{H}$  NMR (300.072 MHz,  $(\text{CD}_3)_2\text{CO}$ ):  $\delta$  2.76-2.91 (m, 1H), 3.00-3.29 (m, 3H), 7.34 (d, 2H,  $J = 8.4$  Hz), 7.55-7.62 (m, 3H), 7.70 (dd, 2H,  $J = 1.5, 8.1$  Hz), 7.76 (d, 2H,  $J = 8.1$  Hz), 8.08 (broad s, 1H), 10.70 (broad s, 1H).
- 25  $^{13}\text{C}$  NMR (75.46 MHz,  $(\text{CD}_3)_2\text{CO}$ ):  $\delta$  28.3 (t), 57.8 (t), 2 X 124.8 (d), 128.0 (d), 2 X 129.6 (d), 2 X 130.0 (d), 131.5 (d), 144.1 (s), 145.7 (s).

**Example 29**

**N-Hydroxy-3-[4-(3-phenylpropyl)-phenyl]-propanamide (77)**

30



### Step 1: 3-(4-bromophenyl)-propanoic acid (74)

Under nitrogen atmosphere in a 250 mL round bottomed flask containing 4-bromocinnamic acid (5.0 g, 22 mmoles) in 45 mL of N,N-dimethylformamide (0.5 M) was added benzenesulfonylhydrazide (7.6 g, 44 mmoles). The mixture was stirred at reflux for 12 hours. The solution was cooled at room temperature, aqueous saturated ammonium chloride was added and the aqueous layer was extracted with ethyl acetate 3 times. Combined organic layers were washed with water and brine, dried over anhydrous magnesium sulfate, filtered and concentrated under vacuo. The resulting solid was purified by flash chromatography eluting with 5 % methanol: 95% dichloromethane to afford 3.66 g (73%) of beige solid.

<sup>1</sup>H NMR (300 MHz, CDCl<sub>3</sub>): δ 2.66 (t, 2H, J = 7.5 Hz), 2.91 (d, 2H, J = 7.5 Hz), 7.08 (d, 2H, J = 8.4 Hz), 7.41 (d, 2H, J = 8.4 Hz).

### Step 2: N-Hydroxy-3-(4-bromophenyl)-propanamide (75)

Following a procedure analogous to that described for the preparation of 70, 1.54 g (39 %) of the title compound was obtained.

<sup>1</sup>H NMR (300 MHz, CDCl<sub>3</sub>): δ 2.39 (t, 2H, J = 7.8 Hz), 2.89 (d, 2H, J = 7.2 Hz), 7.18 (d, 2H, J = 8.1 Hz), 7.42 (d, 2H, J = 8.7 Hz), 8.18 (broad s, 1H), 9.98 (broad s, 1H).

5    Step 3: N-Hydroxy-3-[4-(3-phenyl-1-propenyl)-phenyl]-propanamide and N-Hydroxy-3-[4-(3-phenyl-2-propenyl)-phenyl]-propanamide (76)

Following a procedure analogous to that described in Example 25, step 1, but substituting N-hydroxy-3-(4-bromophenyl)-propanamide (75) (250 mg, 1.02 mmol) for 4-bromobenzoic acid and allyl benzene (163  $\mu$ L, 1.2 mmol) for 4-phenyl-1-butene, to yield 155.4 mg (54 %) of the mixed title compounds.

10     $^1\text{H}$  NMR (300 MHz,  $\text{CDCl}_3$ ):  $\delta$  2.39 (m, 2H), 2.88 (t, 2H,  $J = 8.4$  Hz), 3.51 (t, 2H,  $J = 8.1$  Hz), 6.32-6.53 (m, 2H), 7.14-7.44 (m, 9H), 8.60 (broad s, 1H), 10.04 (broad s, 1H).

15    Step 4: N-Hydroxy-3[4-(3-phenylpropyl)-phenyl]-propanamide (77)

Following a procedure analogous to that described in Example 24, step 2, but substituting the mixture of N-hydroxy-3-[4-(3-phenyl-1-propenyl)-phenyl]-propanamide and N-hydroxy-3-[4-(3-phenyl-2-propenyl)-phenyl]-propanamide (155 mg, 0.55 mmol) for olefins 54, 155.4 mg (99 %) of the title compound was

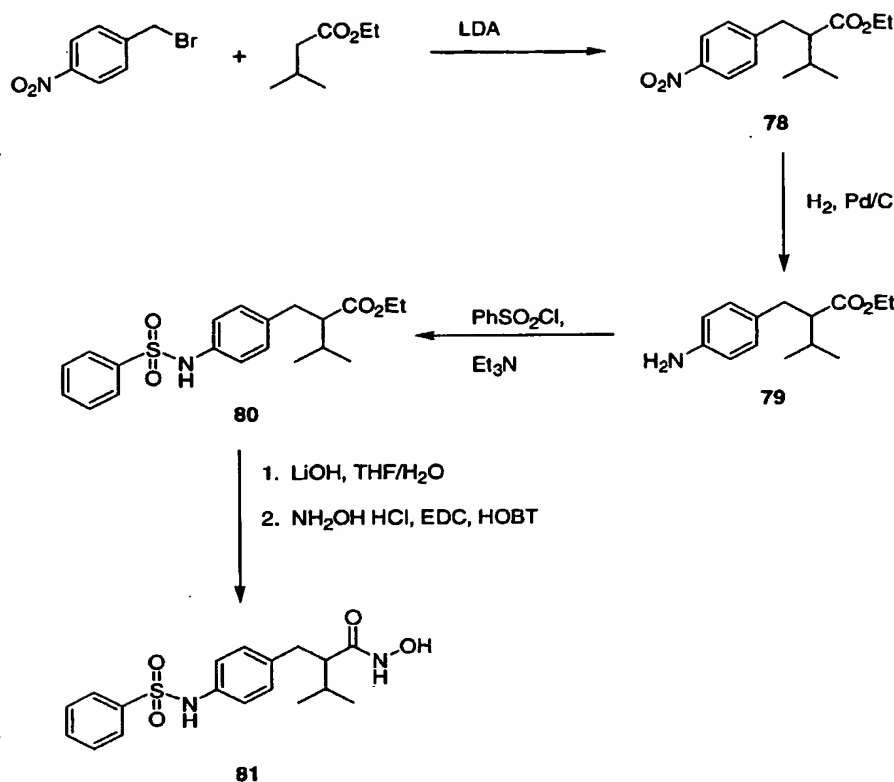
20    obtained.

RP-HPLC: (Hewlett-Packard 1100, column C18 HP 4.6x250mm, flow 1 mL/min, 10-95 %  $\text{CH}_3\text{CN}$  /  $\text{H}_2\text{O}$  in 42 min with 0.1 % TFA); Purity: 99.9% (220 nm) (2 peaks but same compound proven by LCMS, 99.9% (254 nm).  $^1\text{H}$  NMR (300.072 MHz,  $(\text{CD}_3)_2\text{CO}$ ):  $\delta$  1.91 (quintuplet, 2H,  $J = 8.1$  Hz), 2.38 (t, 2H,  $J = 7.8$  Hz), 2.61 (q, 4H,  $J = 9.6$  Hz), 2.87 (t, 2H,  $J = 7.2$  Hz), 7.12-7.29 (m, 9H), 8.42 (broad s, 1H), 10.01 (broad s, 1H).

25     $^{13}\text{C}$  NMR (75.46 MHz,  $(\text{CD}_3)_2\text{CO}$ ):  $\delta$  26.3 (t), 28.7 (t), 29.8 (t), 30.3 (t), 30.7 (t), 121.1 (d), 3 X 123.7 (d), 3 X 123.8 (d), 133.9 (s), 133.4 (s), 137.8 (s), 164.9 (s).

Elemental Analysis; Calc for  $\text{C}_{18}\text{H}_{21}\text{O}_2\text{N} \times 0.1 \text{ H}_2\text{O}$ : % C = 75.81, % H = 7.49, % N = 4.91. Found: % C =  $75.7 \pm 0.3$ , % H =  $7.54 \pm 0.02$ , % N =  $4.85 \pm 0.03$ .

30

5 **Example 30****Step 1: Ethyl 3-(4-nitrophenyl)-2-isopropyl propanoate (78)**

To a precooled solution of diisopropylamine (34.7 mmol) in THF (30 mL) under nitrogen was added dropwise a 1.0 M solution of *n*-butyllithium (33.3 mmol). The resulting light yellow solution was stirred at  $-78^\circ\text{C}$  over 30 minutes and transferred via canula to a precooled ( $-78^\circ\text{C}$ ) solution of ethyl isovalerate (34.7 mmol) in THF (50 mL). The mixture was stirred at  $-78^\circ\text{C}$  over 1 hour and a 4-nitrobenzyl bromide (13.9 mmol) solution in THF (20 mL) at room temperature was transferred dropwise via canula to the enolate solution which turned deep red. The mixture was stirred over 15 minutes and the reaction was quenched with aqueous saturated ammonium chloride solution ( $\text{NH}_4\text{Cl}$ ). The mixture was allowed to warm to room temperature over 1 hour and turned brown upon warming. It was poured into a large volume of saturated  $\text{NH}_4\text{Cl}$  solution and

5 the layers were separated. The aqueous layer was extracted twice with diethyl ether and the combined organic layers were washed with brine, dried over magnesium sulfate and concentrated *in vacuo*. The residue was purified by flash chromatography on silica gel using ethyl acetate and hexanes (10:90) as the eluent, yielding 73% of the pure title compound 78 as a light yellow oil.

10 Step 2: Ethyl 3-(4-aminophenyl),2-isopropyl propanoate (79):

To a hydrogen flushed (vacuum/H<sub>2</sub>, 3 times) solution of 1 (1.88 mmol) in methanol (10 mL) was added 10% palladium on charcoal (0.018 mmol) previously quenched with methanol in a separate flask. The black heterogeneous resulting mixture was stirred at room temperature under  
15 hydrogen atmosphere (1 atm) over 20 hours. The hydrogen was then evacuated by vacuum and replaced with air. Then, the mixture was filtered through celite, rinsing with methanol while making sure the pad never gets dry. The filtrate was concentrated to a red oil. The residue was purified by flash chromatography on silica gel using ethyl acetate and hexanes (30:70) as the eluent, yielding 73% of  
20 the pure title compound 79 as a light red oil.

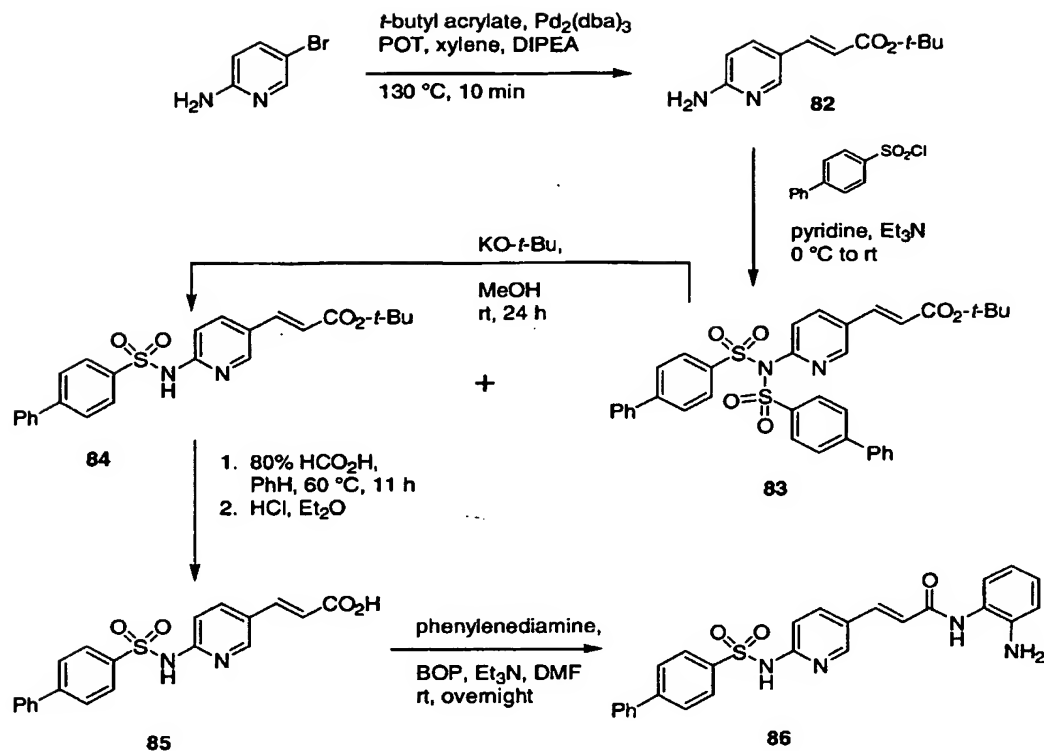
Steps 3-5: (81)

Compound 79 was coupled with benzenesulfonyl chloride in the presence of triethylamine according to the procedure described in Example 1, step 1, to afford the sulfonamide 80. Ester hydrolysis and coupling with hydroxylamine  
25 were then accomplished as described in Example 28 to afford the hydroxamic acid 81.

<sup>1</sup>H NMR: (Acetone-d<sub>6</sub>) δ(ppm): 9.76 (bs, 1H), 8.83 (bs, 1H), 7.74 (d, J=8.2 Hz, 2H), 7.59-7.49 (m, 3H), 7.04 (s, 4H), 2.83-2.73 (m, 3H), 1.83 (sext, J=6.9 Hz, 1H), 1.00 (d, J=6.9 Hz, 3H), 0.93 (d, J=6.9 Hz, 3H).

30 HRMS: 344.1195 (M<sup>+</sup> -H<sub>2</sub>O) (calc.); 344.1200 ±0.0010 (found).



5 **Example 31:**

Compound **82** was obtained in good yield from commercially available bromoaminopyridine through a palladium catalyzed coupling with *tert*-butyl acrylate. Treatment of **82** with 4-phenylbenzenesulfonyl chloride afforded a mixture of sulfonamide **84** and bis-sulfonamide **83**, which was converted to **84** upon chromatographic isolation followed by basic methanolysis. Acidic cleavage of the *t*-butyl ester was effected by treatment of **84** with aqueous formic acid and a *tert*-butyl cation scavenger to afford the acrylic acid **85** in quantitative yield. Finally, coupling of **85** with *o*-phenylenediamine in the presence of benzotriazol-1-yloxytris(dimethylamino)phosphonium hexafluorophosphate (BOP) afforded the anilide **86**.

Data for **86**:

$^1\text{H}$  NMR: (300.07 MHz;  $\text{CD}_3\text{OD}$ ) :  $\delta$  (ppm): 8.23 (d,  $J=1.9$ , 1H); 8.03 (bd,  $J=8.5$ ; 2H); 7.96 (dd,  $J=1.9, 9.1$ ; 1H); 7.76 (bd,  $J=8.5$ , 2H); 7.63 (dd,  $J=1.4, 8.2$ ); 7.53 ( $J=$

5 15.5; 1H), 7.48-7.36 (m, 3H); 7.29 (d, J = 9.1, 1H) 7.18 (dd, J = 1.4, 8.0, 1H); 7.03 (dt, J = 1.4, 7.8, 1H); 6.86 (d, J = 1.4, 7.9, 1H) 6.76 (d, J = 15.6, 1H) 6.75-6.69 (m, 1H); 4.85 (bs, 4H).

<sup>13</sup>C NMR: (75.5 MHz; CD<sub>3</sub>OD) (ppm): 166.4; 154.7; 146.9; 146.2; 143.1; 141.1;

140.6; 138.6; 137.9; 130.1; 129.5; 128.8; 128.5; 128.3; 126.7; 125.6; 125.0; 122.1; 120.8;

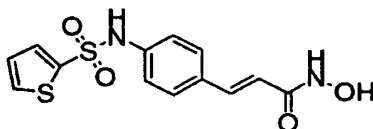
10 119.5; 118.6; 114.9

MS: calc for C<sub>26</sub>H<sub>22</sub>O<sub>3</sub>N<sub>4</sub>S: 470.556; found: 471.5 for [M+H] (low resolution MS).

By procedures analogous to those described in Examples 1-31 above, the following compounds were synthesized:

15

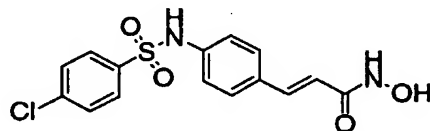
87



20 <sup>1</sup>H NMR: (300 MHz, CD<sub>3</sub>OD): d = 7.76-7.74 (1H, m), 7.58-7.48 (4H, m), 7.22 (2H, d, J = 7.5 Hz), 7.10 (1H, t, J = 5.1 Hz), 6.41 (1H, d broad, J = 14.7 Hz).

25

88

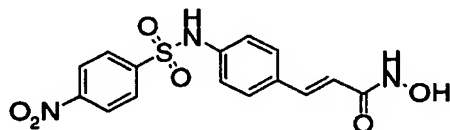


<sup>1</sup>H NMR: (300 MHz, CD<sub>3</sub>OD): d = 7.79 (2H, d, J = 8.1 Hz), 7.56-7.46 (5H, m), 7.17 (2H, d, J = 8.1 Hz), 6.39 (1H, d, J = 15.9 Hz).

Analysis: C<sub>15</sub>H<sub>13</sub>N<sub>2</sub>O<sub>4</sub>SCl X 0.1 H<sub>2</sub>O, X 0.3 TFA Found: C=48.26%, H=3.58%,

30 N=6.97%, S=7.86%. Calc.: C=48.19%, H=3.50%, N=7.20%, S=8.25%

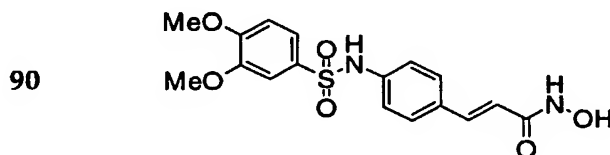
89



- 5 <sup>1</sup>H NMR: (300 MHz, DMSO d<sub>6</sub>): d = 10.85 (1H, s br), 10.70 (1H, s br), 8.99 (1H, s), 8.37 (2H, d, J = 9 Hz), 8.01 (2H, d, J = 9 Hz), 7.44 (2H, d, J = 8.7 Hz), 7.33 (1H, d, J = 15.3 Hz), 7.12 (2H, d, J = 8.4 Hz), 6.31 (1H, d, J = 15.9 Hz).

Analysis: C<sub>15</sub>H<sub>13</sub>N<sub>3</sub>O<sub>6</sub>S X 0.4 H<sub>2</sub>O, X 0.3 TFA Found: C=46.39%, H=3.49%, N=10.44%, S=7.92%. Calc.: C=46.29%, H=3.51%, N=10.38%, S=7.92%.

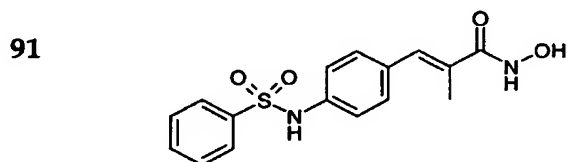
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- 15 <sup>1</sup>H NMR: (300 MHz, DMSO d<sub>6</sub>): d = 10.70 (1H, s br), 10.33 (1H, s br), 8.99 (1H, s br), 7.44-7.26 (5H, m), 7.12 (2H, d, J = 8.7 Hz), 7.06 (1H, d, J = 8.4 Hz), 6.30 (1H, d, J = 16.2 Hz), 3.78 (3H, s), 3.75 (3H, s)

Analysis: C<sub>17</sub>H<sub>18</sub>N<sub>2</sub>O<sub>6</sub>S X 0.2 H<sub>2</sub>O Found: C=53.56%, H=5.03%, N=7.71%, S=8.01%. Calc.: C=53.45%, H=4.86%, N=7.33%, S=8.39%.

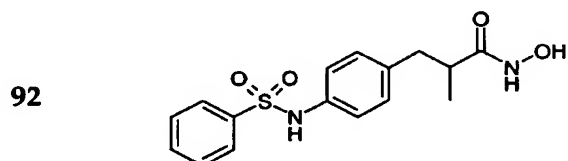
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- 25 <sup>1</sup>H NMR: (CD<sub>3</sub>OD) δ(ppm): 7.78 (d, J=7.1 Hz, 1H), 7.56-7.45 (m, 3H), 7.24 (d, J=8.5 Hz, 2H), 7.12 (d, J=8.8 Hz, 2H), 7.06 (s, 1H), 2.00 (d, J=1.4 Hz, 3H).

<sup>13</sup>C NMR: (CD<sub>3</sub>OD) δ(ppm): 135.2, 132.9, 128.1, 127.7, 125.5, 124.6, 124.1, 122.3, 116.8, 115.6, 8.4.

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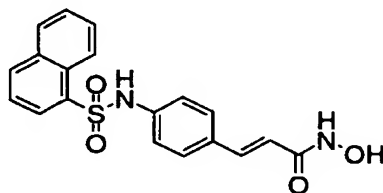


5 <sup>1</sup>H NMR: (Acetone-d<sub>6</sub>) δ(ppm): 9.86 (bs, 1H), 8.86 (bs, 1H), 7.83 (bs, 1H), 7.76 (d, J=6.7 Hz, 1H), 7.62-7.48 (m, 3H), 7.10-7.03 (m, 4H), 2.87-2.79 (m, 3H), 2.56-2.39 (m, 2H), 1.05 (d, J=6.6 Hz, 3H).

HRMS: 334.0987 (calc.); 334.0991 ±0.0010 (found)

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93

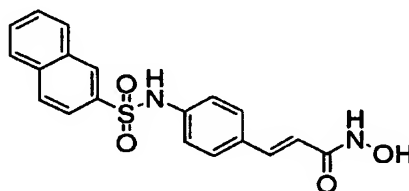


<sup>1</sup>H NMR: (300 MHz, DMSO d<sub>6</sub>): δ = 10.94 (1H, s broad), 10.65 (1H, s broad), 8.95 (1H, s Broad), 8.73-8.71 (1H, m), 8.24-8.21 (2H, m), 8.05 (1H, m), 7.74-7.63 (3H, m), 7.33-7.23 (2H, m), 7.06-7.04 (2H, m), 6.24 (1H, d, J = 15.3).

Analysis: C<sub>19</sub>H<sub>16</sub>N<sub>2</sub>O<sub>4</sub>S X 0.5 H<sub>2</sub>O Found: C=60.31%, H=4.58%, N=7.43%. Calc.: C=60.46%, H=4.54%, N=7.42%

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94

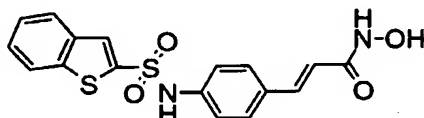


<sup>1</sup>H NMR: (300 MHz, DMSO d<sub>6</sub>): δ = 10.65 (2H, s broad), 8.48 (1H, s), 8.15-8.08 (2H, m), 8.00 (1H, d, J = 7.5 Hz), 7.77 (1H, d, J = 9 Hz), 7.70-7.62 (2H, m), 7.39 (2H, d, J = 8.4 Hz), 7.28 (1H, d, J = 15.6 Hz), 7.15 (2H, d, J = 8.4 Hz), 6.26 (1H, d, J = 15.6 Hz).

Analysis: C<sub>19</sub>H<sub>16</sub>N<sub>2</sub>O<sub>4</sub>S X 0.2 H<sub>2</sub>O, X 0.5 TFA Found: C=56.01%, H=3.94%, N=6.60%, S=7.41%. Calc.: C=55.99%, H=3.97%, N=6.53%, S=7.47%.

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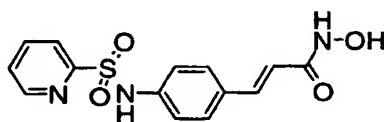
95



- 5 <sup>1</sup>H NMR: (300 MHz, DMSO d<sub>6</sub>): δ = 10.91 (1H, s), 10.69 (1H, s br), 8.06-7.98 (3H, m), 7.57-7.46 (4H, m), 7.34 (1H, d, J = 15.9 Hz), 7.21 (2H, d, J = 8.4 Hz), 6.33 (1H, d, J = 15.9 Hz).

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96

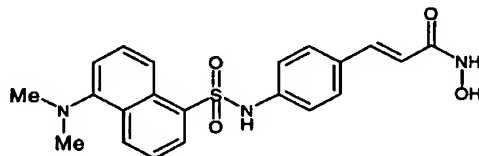


<sup>1</sup>H NMR: (300 MHz, DMSO d<sub>6</sub>): δ = 8.69-8.8 (1H, m), 8.02-8.01 (2H, m), 7.61-7.59 (1H, m), 7.52-7.43 (3H, m), 7.25 (2H, d, J = 7.5 Hz), 6.37 (1H, d, J = 15.9 Hz).

Analysis: C<sub>14</sub>H<sub>13</sub>N<sub>3</sub>O<sub>4</sub>S X 0.9 TFA Found: C=45.36%, H=3.51%, N=9.77%, S=7.09%.

- 15 Calc.: C=44.97%, H=3.32%, N=9.96%, S=7.60 %.

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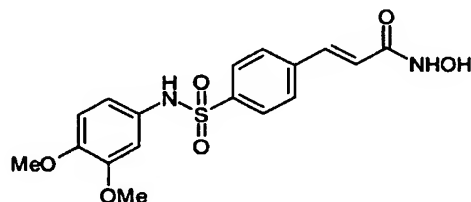


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<sup>1</sup>H NMR: (300 MHz, DMSO d<sub>6</sub>): δ = 10.91 (1H, s), 10.62 (1H, s br), 8.45 (1H, 8.1 Hz), 8.36 (1H, d, J = 8.7 Hz), 8.25 (1H, d, J = 6.9 Hz), 7.65-7.59 (2H, m), 7.37-7.34 (2H, m), 7.29-7.23 (2H, m), 7.06 (2H, d, J = 8.7 Hz), 6.25 (1H, d, J = 15.9 Hz) 2.80 (6H, s).

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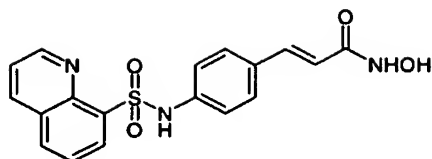
98



- 30 <sup>1</sup>H NMR: (300 MHz, DMSO d<sub>6</sub>): δ = 10.82 (1H, s br), 9.95 (1H, s br), 9.12 (1H, s br), 7.70 (4H, s), 7.46 (1H, d, J = 15.9 Hz), 6.79 (1H, d, J = 8.7 Hz), 6.68 (1H, s), 6.56-6.51 (2H, m), 3.65 (3H, s), 3.62 (3H, s).

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99

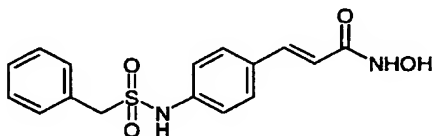


- 10 <sup>1</sup>H NMR: (300 MHz, DMSO d<sub>6</sub>): δ = 10.63 (1H, s), 10.36 (1H, s br), 9.13-9.12 (1H, m), 8.93 (1H, s br), 8.51 (1H, d, J = 8.1 Hz), 8.40 (1H, d, J = 7.2 Hz), 8.28 (1H, d, J = 8.4 Hz), 7.75-7.70 (2H, m), 7.30-7.20 (3H, m), 7.09 (2H, d, J = 8.4 Hz) 6.21 (1H, d, J = 15.9 Hz).

Analysis: C<sub>18</sub>H<sub>15</sub>N<sub>3</sub>O<sub>4</sub>S X 1.1 H<sub>2</sub>O Found: C=55.72%, H=4.45%, N=10.64%,

- 15 S=6.93%. Calc.: C=55.55%, H=4.45%, N=10.80%, S=8.24%.

100



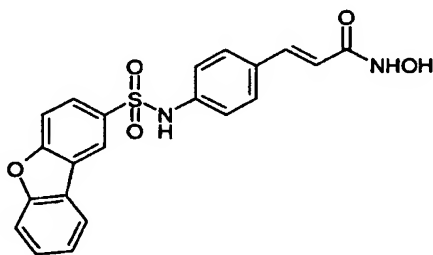
- 20 <sup>1</sup>H NMR: (300 MHz, DMSO d<sub>6</sub>): δ = 10.72 (1H, s br), 10.07 (1H, s), 7.53-7.51 (2H, m), 7.43-7.34 (4H, m), 7.26-7.19 (4H, m), 6.38 (1H, d, J = 15.6 Hz), 4.51 (2H, s).

Analysis: C<sub>16</sub>H<sub>16</sub>N<sub>2</sub>O<sub>4</sub>S X 0.4 TFA Found: C=53.60%, H=4.46%, N=7.36%, S=7.81%.

Calc.: C=53.38%, H=4.37%, N=7.41%, O=20.32%, S=8.48%, F=6.03%.

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101

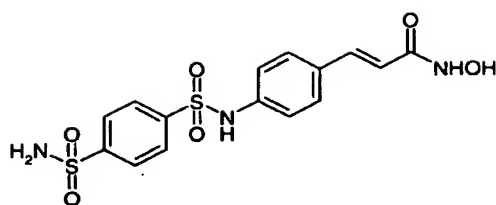


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<sup>1</sup>H NMR: (300 MHz, DMSO d<sub>6</sub>): δ = 10.63 (1H, s br), 10.56 (1H, s), 8.67 (1H, s), 8.29 (1H, d, J = 6.9 Hz), 7.89-7.85 (2H, m), 7.75 (1H, d, J = 8.4 Hz), 7.59 (1H, t, J = 7.2 Hz), 7.47-7.38 (3H, m), 7.27 (1H, d, J = 15.6 Hz), 7.15 (2H, d, J = 8.7 Hz), 6.25 (1H, d, J = 15.9 Hz).

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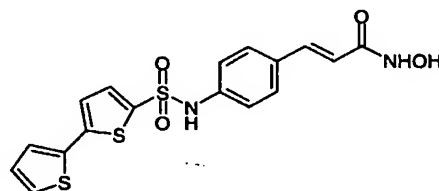
102



10  $^1\text{H}$  NMR: (300 MHz, DMSO  $d_6$ ):  $\delta$  = 10.72 (2H, s), 8.98 (1H, s br), 7.97 (4H, s), 7.55 (2H, s), 7.45 (2H, d,  $J$  = 8.7 Hz), 7.33 (1H, d,  $J$  = 15.9 Hz), 7.13 (2H, d,  $J$  = 8.7 Hz), 6.32 (1H, d,  $J$  = 15.9 Hz).

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103



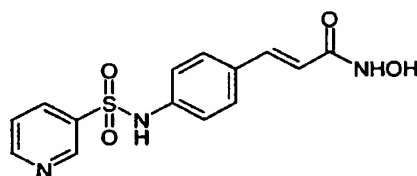
1H NMR: (300 MHz, DMSO  $d_6$ ):  $\delta$  = 10.75 (2H, m), 7.65-7.64 (1H, m), 7.53-7.45 (4H, m), 7.35 (1H, d,  $J$  = 16.2 Hz), 7.29 (1H, d,  $J$  = 3.9 Hz), 7.20 (2H, d,  $J$  = 8.7 Hz), 7.12 (1H, t,  $J$  = 3.6 Hz), 6.34 (1H, d,  $J$  = 15.6 Hz).

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Analysis:  $\text{C}_{17}\text{H}_{14}\text{N}_2\text{O}_4\text{S}_3 \cdot 0.1 \text{H}_2\text{O} \cdot 1.0 \text{TFA}$  Found: C=43.83%, H=3.26%, N=5.73%, S=18.15%. Calc.: C=43.69%, H=2.93%, N=5.36%, S=18.42%.

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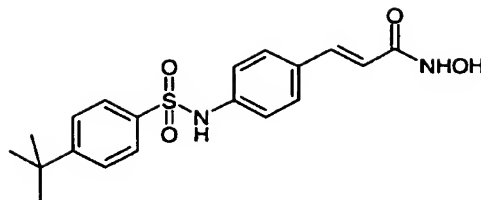
104



30  $^1\text{H}$  NMR: (300 MHz, DMSO  $d_6$ ):  $\delta$  = 10.72 (1H, s), 8.91 (1H, d,  $J$  = 1.8 Hz), 8.80-8.78 (1H, m), 8.13 (1H, d,  $J$  = 7.8 Hz), 7.63-7.59 (1H, m), 7.46 (2H, d,  $J$  = 8.7 Hz), 7.33 (1H, d,  $J$  = 15.6 Hz), 7.14 (2H, d,  $J$  = 8.7 Hz), 6.32 (1H, d,  $J$  = 15.9 Hz).

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105



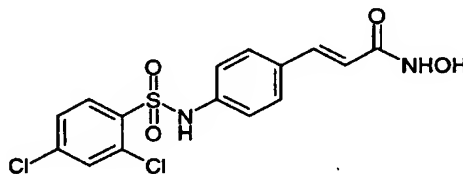
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<sup>1</sup>H NMR: (300 MHz, DMSO d<sub>6</sub>): δ = 10.54 (1H, s), 7.73 (2H, d, J = 8.4 Hz), 7.58 (2H, d, 8.4 Hz), 7.43 (2H, d, J = 8.4 Hz), 7.32 (1H, d, J = 15.6 Hz), 7.15 (2H, d, J = 8.4 Hz), 6.30 (1H, d, J = 15.9 Hz), 1.25 (9H, s).

Analysis: C<sub>19</sub>H<sub>22</sub>N<sub>2</sub>O<sub>4</sub>S X 0.3 H<sub>2</sub>O, 0.6 TFA Found: C=54.17%, H=5.25%, N=6.32%,

15 S=6.85%. Calc.: C=54.12%, H=5.22%, N=6.25%, S=7.15%.

106



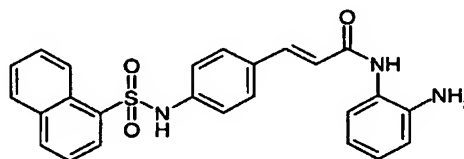
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<sup>1</sup>H NMR: (300 MHz, DMSO d<sub>6</sub>): δ = 11.02 (1H, s), 10.70 (1H, s), 8.99 (1H, s br), 8.03 (1H, d, J = 1.8 Hz), 7.76-7.67 (2H, m), 7.45 (2H, d, J = 8.1 Hz), 7.33 (1H, d, J = 15.6 Hz), 7.13 (2H, d, J = 8.4 Hz), 6.31 (1H, d, J = 16.2 Hz).

Analysis: C<sub>15</sub>H<sub>12</sub>N<sub>2</sub>O<sub>4</sub>SCl<sub>2</sub> X 0.3 H<sub>2</sub>O Found: C=45.96%, H=3.11%, N=7.21%,

25 S=8.06%. Calc.: C=45.89%, H=3.23%, N=7.13%, S=8.17%.

107



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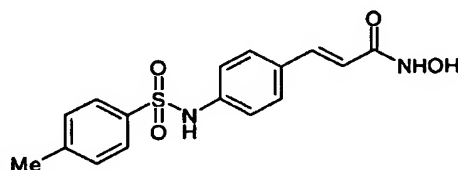
<sup>1</sup>H NMR: (300 MHz, Acetone d<sub>6</sub>): δ = 8.81 (1H, d, J = 8.4 Hz), 8.34 (2H, d, J = 7.2 Hz), 8.20 (1H, d, J = 8.1 Hz), 8.05 (1H, d, J = 7.5 Hz), 7.75-7.59 (4H, m), 7.53-7.41 (4H, m), 7.23-7.07 (4H, m), 6.89-6.86 (2H, m), 6.75 (1H, d, J = 15.3 Hz).



- 5 Analysis:  $C_{25}H_{21}N_3O_3S \times 0.4 H_2O, 0.6 TFA$  Found: C=60.68%, H=4.36%, N=8.11%, S=6.15%. Calc.: C=60.62%, H=4.35%, N=8.09%, S=6.18%.

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108

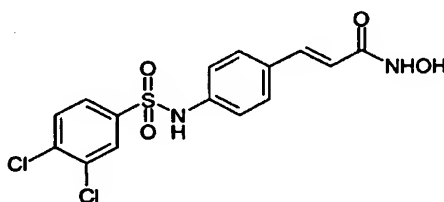


$^1H$  NMR: (300 MHz, DMSO  $d_6$ ):  $\delta$  = 10.7 (1H, s br), 10.45 (1H, s br), 8.96 (1H, s br), 7.64 (2H, d, J = 8.1 Hz), 7.38 (2H, d, J = 8.4 Hz), 7.32-7.29 (3H, m), 7.09 (2H, d, J = 8.4 Hz), 6.29 (1H, d, J = 16.2 Hz), 2.30 (3H, s).

- 15 Analysis:  $C_{16}H_{16}N_2O_4S \times 1.6 H_2O, \times 1.6 TFA$  Found: C=42.26%, H=3.62%, N=5.45%, S=6.09%. Calc.: C=42.42%, H=3.86%, N=5.15%, S=5.9%.

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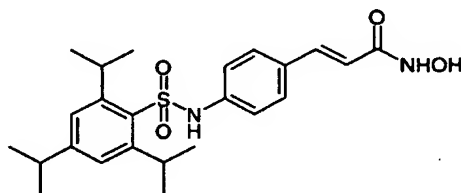
$^1H$  NMR: (300 MHz, DMSO  $d_6$ ):  $\delta$  = 10.71 (1H, s), 10.67 (1H, s), 9.00 (1H, s br), 7.96 (1H, d, J = 2.4 Hz), 7.85 (1H, d, J = 8.4 Hz), 7.69 (1H, dd, J = 8.4 Hz and 2.1 Hz), 7.47 (2H, d, J = 8.4 Hz), 7.35 (1H, d, J = 15.9 Hz), 7.13 (2H, d, J = 8.7 Hz), 6.33 (1H, d, J = 15.9 Hz).

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Analysis:  $C_{15}H_{12}N_2O_4SCl_2 \times 0.3 H_2O, \times 0.3 AcOEt$  Found: C=46.30%, H=3.27%, N=6.56%, S=7.57%. Calc.: C=46.43%, H=3.61%, N=6.68%, S=7.65%.

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110



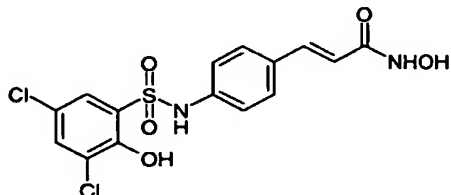
$^1H$  NMR: (300 MHz, DMSO  $d_6$ ):  $\delta$  = 10.65 (1H, s br), 10.45 (1H, s br), 8.96 (1H, s br), 7.42 (2H, d, J = 8.1 Hz), 7.31 (1H, d, J = 15.6 Hz), 7.22 (2H, s), 7.01 (2H, d, J =

5 8.1 Hz), 6.30 (1H, d, J = 15.9 Hz), 4.24-4.16 (2H, m), 2.93-2.84 (1H, m), 1.18-1.14 (18H, m).

Analysis:  $C_{24}H_{32}N_2O_4S \times 1.10 H_2O$  Found: C=62.14%, H=7.17%, N=6.20%, S=6.71%. Calc.: C=62.07%, H=7.42%, N=6.03%, S=6.9%.

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111



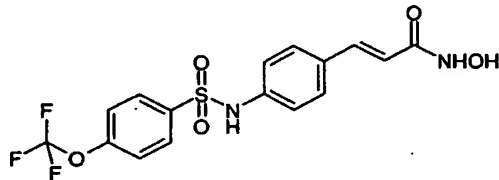
$^1H$  NMR: (300 MHz, DMSO  $d_6$ ):  $\delta$  = 11.18 (1H, s br), 10.69 (2H, m), 7.83-7.82 (1H, m), 7.68 (1H, m), 7.43 (2H, d, J = 8.1 Hz), 7.32 (1H, d, J = 15.3 Hz), 7.13 (2H, d, J = 8.1 Hz), 6.31 (1H, d, J = 15.9 Hz).

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Analysis:  $C_{15}H_{12}N_2O_5SCl_2 \times 0.2 H_2O, \times 0.2 TFA$  Found: C=43.14%, H=3.04%, N=6.54%, S=7.19%. Calc.: C=43.05%, H=2.96%, N=6.52%, S=7.46%.

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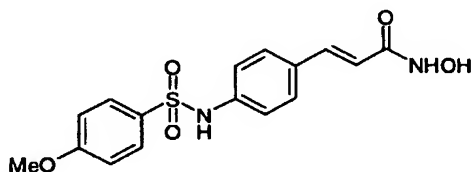
$^1H$  NMR: (300 MHz, DMSO  $d_6$ ):  $\delta$  = 10.70 (1H, s), 10.65 (1H, s), 9.01 (1H, s br), 7.91 (2H, d, J = 8.4 Hz), 7.56 (2H, d, J = 8.4 Hz), 7.45 (2H, d, J = 8.1 Hz), 7.33 (1H, d, J = 15.6 Hz), 7.13 (2H, d, J = 8.1 Hz), 6.31 (1H, J = 15.6 Hz).

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Analysis:  $C_{16}H_{13}N_2O_5SF_3 \times 0.2 TFA$  Found: C=46.43%, H=3.33%, N=6.22%, S=7.25%. Calc.: C=46.33%, H=3.13%, N=6.59%, S=7.54%.

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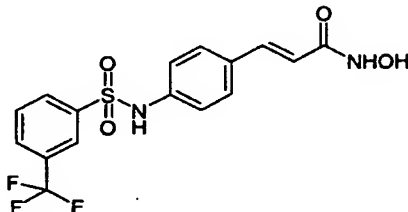


- 5 <sup>1</sup>H NMR: (300 MHz, DMSO d<sub>6</sub>): = 10.66 (1H, s br), 10.37 (1H, s br), 8.56 (1H, s br), 7.69 (2H, d, J = 8.7 Hz), 7.39 (2H, d, J = 8.1 Hz), 7.30 (1H, d, J = 16.2 Hz), 7.10-7.03 (4H, m), 6.27 (1H, d, J = 15.9 Hz), 3.77 (3H, s).

Analysis: C<sub>16</sub>H<sub>16</sub>N<sub>2</sub>O<sub>5</sub>S X 0.7 H<sub>2</sub>O Found: C=53.32%, H=5.05%, N=7.98%, S=7.78%.  
Calc.: C=53.24%, H=4.86%, N=7.76%, S=8.88%.

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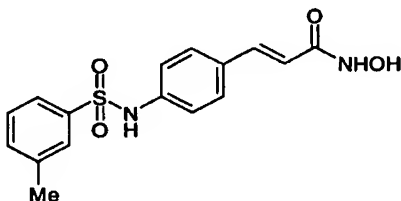


- 15 <sup>1</sup>H NMR: (300 MHz, DMSO d<sub>6</sub>): δ = 10.70 (1H, s), 10.66 (1H, s), 8.99 (1H, s), 8.06-7.98 (3H, m), 7.84-7.79 (1H, m), 7.45 (2H, d, J = 8.4 Hz), 7.33 (1H, d, J = 15.6 Hz), 7.12 (2H, d, J = 8.7 Hz), 6.32 (1H, d, J = 15.9 Hz).

Analysis: C<sub>16</sub>H<sub>13</sub>F<sub>3</sub>N<sub>2</sub>O<sub>4</sub>S Found: C=49.64%, H=3.30%, N=7.18%. Calc.: C=49.74%,  
H=3.39%, N=7.25%

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115

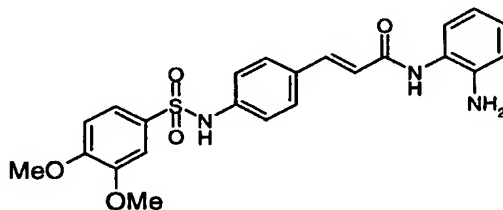


- 25 <sup>1</sup>H NMR: (300 MHz, DMSO d<sub>6</sub>): δ = 10.69 (1H, s, br), 10.47 (1H, s, br), 8.98 (1H, s, br), 7.62 (1H, s), 7.58-7.56 (1H, m), 7.44-7.41 (4H, m), 7.32 (1H, d, J = 16.2 Hz), 7.11 (2H, d, J = 8.1 Hz), 6.30 (1H, d, J = 15.6 Hz), 2.34 (3H, s).

Analysis: C<sub>16</sub>H<sub>16</sub>N<sub>2</sub>O<sub>4</sub>S X 0.3 TFA Found: C=54.64%, H=4.75%, N=7.92%. Calc.:  
C=54.66%, H=4.59%, N=7.82%

30

116



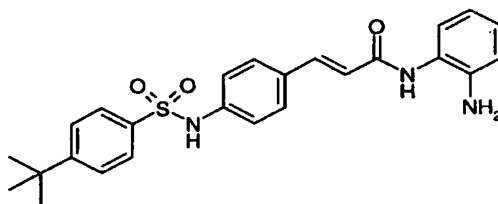
5 <sup>1</sup>H NMR: (300 MHz, MeOD *d*<sub>4</sub>): 7.62-6.61 (m, 13H); 3.81 (broad s, 3H, OCH<sub>3</sub>), 3.80 (broad s, 3H, OCH<sub>3</sub>), 3.26 (broad s, 4H, NH).

<sup>13</sup>C NMR: (75 MHz, MeOD *d*<sub>4</sub>): 167.0 (C=O); 154.4; 150.5; 143.1; 141.9; 141.0; 132.5; 132.3; 129.9; 128.2; 126.7; 125.2; 122.4; 121.8; 120.8; 119.6; 118.7; 111.9; 110.9; 56.6 (2C, OCH<sub>3</sub>).

10 Combustion analysis:      Calc:            60.91% C, 5.11% H, 9.27% N, 7.07% S  
    Found:        60.40% C, 5.21% H, 9.16% N, 6.47% S  
    HRMS:        Calc: 453.1358; Found: 453.1351

15

117

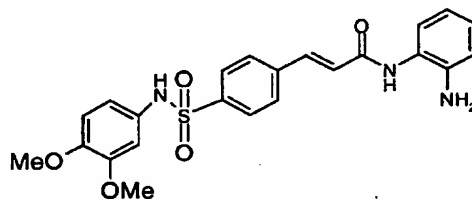


<sup>1</sup>H NMR: (Acetone-*d*<sub>6</sub>): δ(ppm): 9.25 (bs, 1H), 8.77(bs, 1H), 7.79 (d, J=8.5 Hz, 2H), 7.61-7.51 (m, 5H), 7.36-7.28 (m, 3H), 6.99-6.93 (m, 1H), 6.86-6.82 (m, 2H),  
 20 6.68-6.62 (m, 1H), 4.63 (bs, 2H).

HRMS: 449.1773 (calc.) : 449.1767±0.0013 (found)

25

118



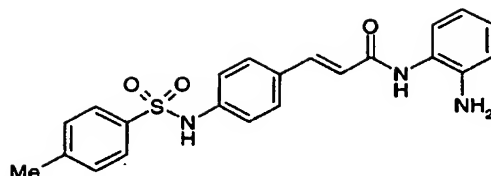
<sup>1</sup>H NMR: (300 MHz, MeOD *d*<sub>4</sub>): 8.00-6.56 (m, 13H); 3.77 (broad s, 3H, OCH<sub>3</sub>), 3.74 (broad s, 3H, OCH<sub>3</sub>), 3.33 (broad s, 2H, NH), 3.00 (broad s, 1H, NH), 2.88 (broad  
 30 s, 1H, NH).

<sup>13</sup>C NMR: (75 MHz, MeOD *d*<sub>4</sub>): 166.2 (C=O); 150.7; 148.5; 143.2; 141.7; 140.6; 140.5; 131.9; 129.2; 128.9; 128.4; 126.7; 124.9; 119.5; 118.6; 116.4; 113.2; 108.9; 56.6 (OCH<sub>3</sub>); 56.4 (OCH<sub>3</sub>).

MS: Calc: 453.1358 : Found: 453.1351

5

119

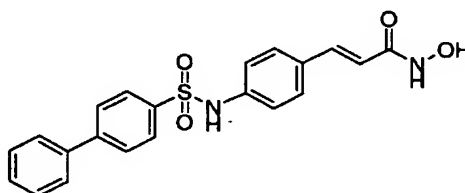


10 <sup>1</sup>H NMR: (CD<sub>3</sub>OD) δ(ppm): 7.68 (d, J=8.2 Hz, 2H), 7.55 (d, J=15.9 Hz, 1H), 7.47 (d, J=8.5 Hz, 2H), 7.30 (d, J= 8.0 Hz, 2H), 7.19-7.12 (m, 3H), 7.03 (t, J=7.1 Hz, 1H), 6.86 (d, J=8.0 Hz, 1H), 6.75-6.69 (m, 2H), 2.37 (s, 3H).

HRMS: 407.1304 (calc.) : 407.1293±0.0012 (found)

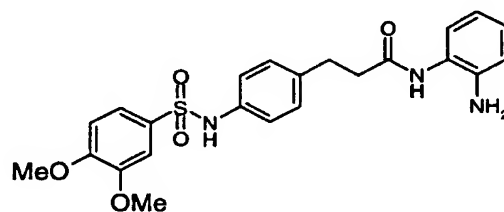
15

120



20 <sup>1</sup>H NMR: (300 MHz, DMSO-*d*<sub>6</sub>) δ 10.6 (s, OH); 9 (s, NH); 7.1-7.8 (m, 14H, CH Ar); 6.2 (d, 1H, J = 15Hz)

121



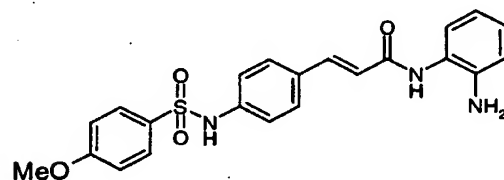
25

<sup>1</sup>H NMR: (300 MHz, MeOD-*d*<sub>4</sub>): 7.31-6.62 (m, 11H); 3.72 (broad s, 3H); 3.70 (broad s, 3H); 2.91 (t, 2H; J= 7.1Hz); 2.65 (broad t, 2H, J=7.4 Hz)

<sup>13</sup>C NMR: (75 MHz, MeOD-*d*<sub>4</sub>): 173.9; 154.0; 150.3; 143.4; 138.6; 137.4; 132.6; 130.2; 128.4; 127.4; 124.6; 123.1; 122.3; 119.3; 118.1; 111.7; 110.9; 56.5 (2C); 38.8; 32.2.

30 HRMS: calc:455.1515 : Found: 455.1521

122



5

<sup>1</sup>H NMR: (300 MHz, DMSO *d*<sub>6</sub>): 7.77 (d, 2H, J=8.8 Hz); 7.51 (d, 2H, J=8.5 Hz); 7.34 (d, 2H, J=8.8 Hz); 7.18 (d, 2H, J=8.5 Hz); 7.11 (d, 2H, 8.8 Hz); 6.94 (t, 1H, J=7.4 Hz); 6.77 (broad d, 2H, J=7.9 Hz); 6.6 (t, 1H, J=7.4 Hz), 4.95 (broad s, 1H), 3.83 (s, 3H).

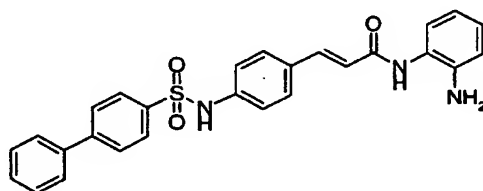
<sup>13</sup>C NMR: (75 MHz, DMSO *d*<sub>6</sub>): 162.5; 141.5; 139.2; 138.8; 130.9; 130.2; 128.9; 128.6;

10 125.7; 124.7; 119.4; 116.2; 115.9; 114.5; 55.6.

HRMS: Calc: 423.1253 : Found: 423.1235

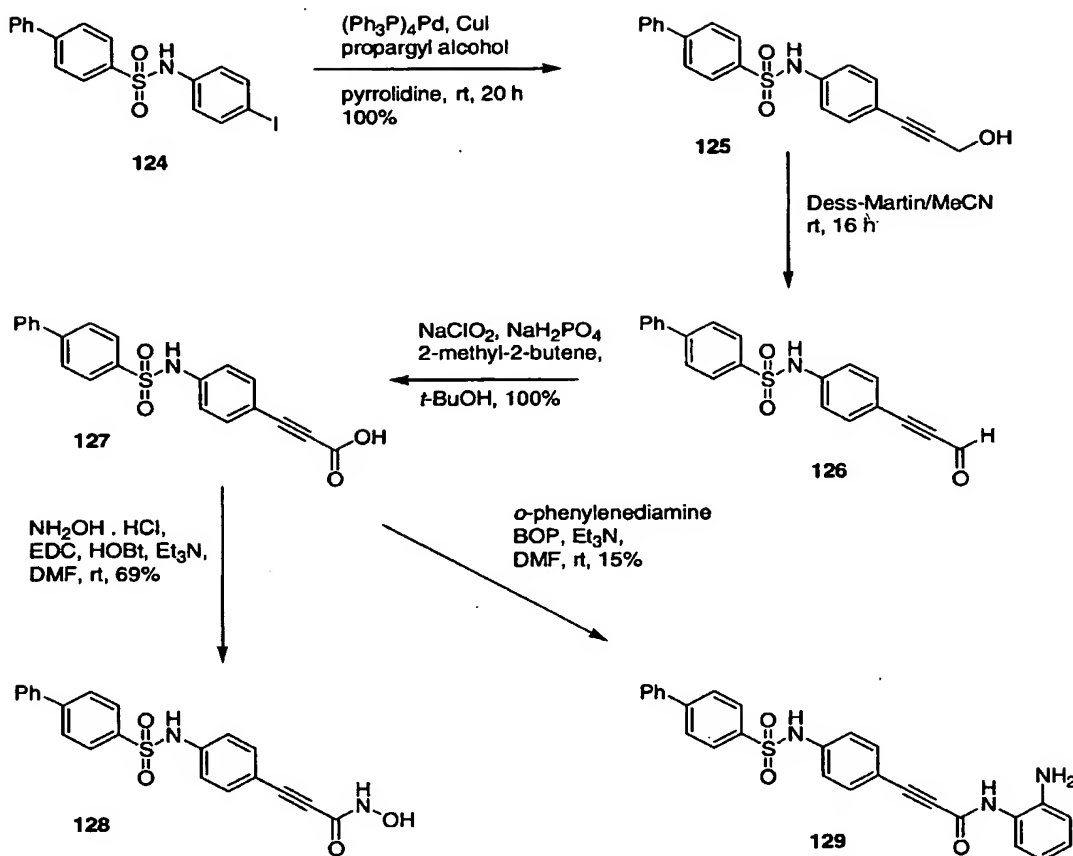
15

123



<sup>1</sup>H NMR: (300 MHz, DMSO-*d*<sub>6</sub>) 7.1-7.8 (m, 14H, CH Ar); 6.8-6.9 (m, 4H, CH Ar); 6.3 (d, 1H, J = 15Hz)

20

5 **Example 32:**

Sulfonamide **124** was prepared by condensation of 4-iodoaniline with  
 10 benzenesulfonyl chloride. Compound **125** was quantitatively furnished by a Pd-  
 Cu catalyzed coupling reaction of **124** with propargyl alcohol in basic solvent.  
 Primary alcohol **125** was oxidized to the corresponding carboxylic acid **127** in  
 two steps, including Dess-Martin periodinane oxidation to afford aldehyde **126**,  
 followed by treatment with sodium chlorite in buffered aqueous media in the  
 15 presence of a chlorine scavenger. Acid **127** was derivatized to the hydroxamic  
 acid **128** by treatment with hydroxylamine hydrochloride and the coupling  
 reagent EDC in the presence of N-hydroxybenzotriazole in basic, aprotic media.

- 5 Compound 129 was prepared by coupling acid 130 with *o*-phenylenediamine as described in Example 31 for compound 86.

Data for 128:

<sup>1</sup>H NMR: (300.07 MHz; acetone-d<sub>6</sub>) δ (ppm): 9.4 (bs, 2H); 7.93 (dd, J= 1.9, 6.6; 2H);  
10 7.82 (dd, J= 1.9, 6.6; 2H); 7.68 (dd, J= 1.4, 8.2; 2H); 7.48-7.41 (m, 5H); 7.35-7.32 (m, 2H); 2.90 (bs, 1H)

<sup>13</sup>C NMR: (75.5 MHz; acetone-d<sub>6</sub>) (ppm): 153.5; 147.2; 141.3; 140.3; 139.5; 134.6; 130.1; 129.5; 128.8; 128.6; 128.3; 120.8; 116.5; 87.7; 81.0.

MS: calc for C<sub>21</sub>H<sub>16</sub>O<sub>4</sub>N<sub>2</sub>S: 392.438; found: 393.4 for [M+H] (low resolution MS).

15

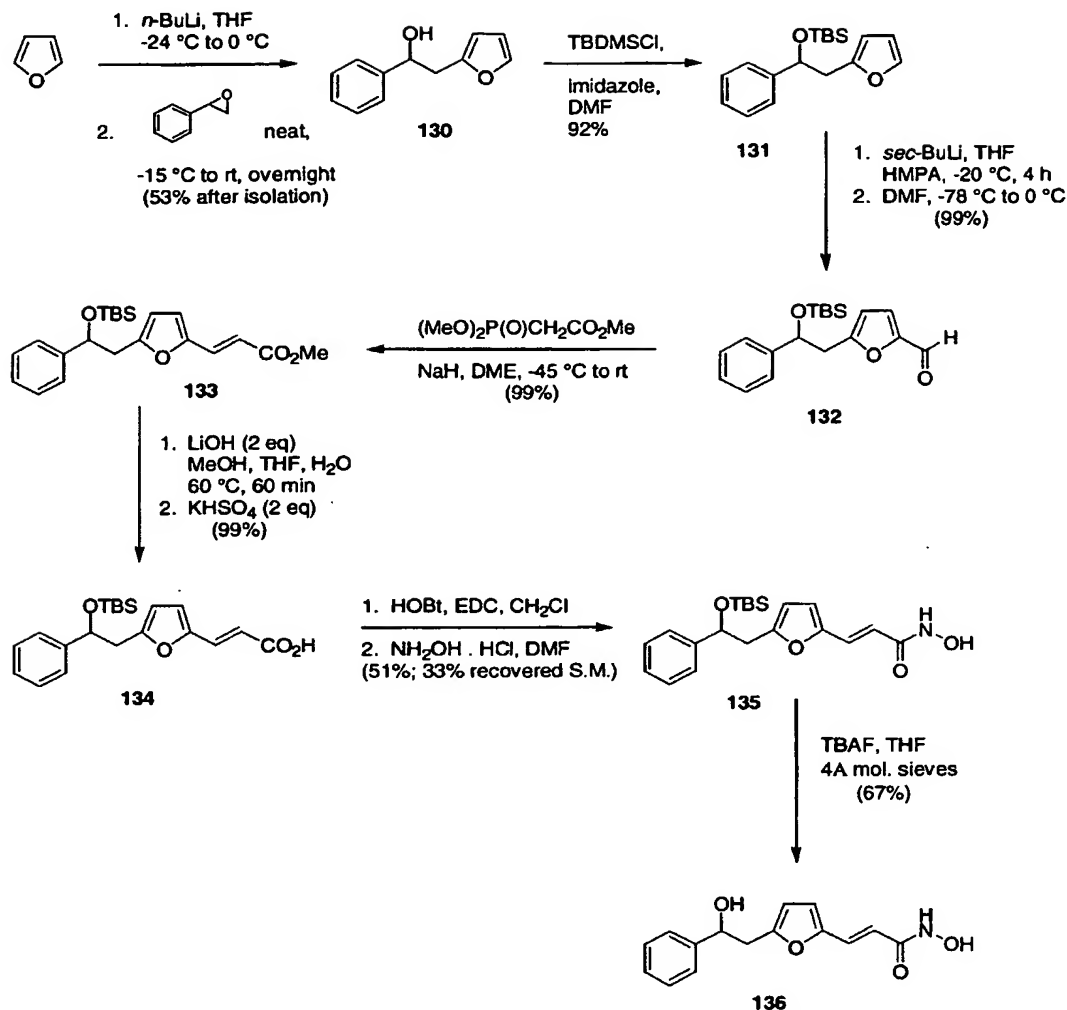
Data for 129:

<sup>1</sup>H NMR: (300.07 MHz; acetone-d<sub>6</sub>) δ (ppm): 9.43 (bs, 1H); 8.02 (d, J= 8.5Hz; 2H);  
7.93 (d, J= 8.5Hz; 2H); 7.90 (d, J= 8.5Hz; 2H); 7.65 (d, J= 8.5Hz; 2H); 7.47-7.34 (m, 7H); 7.21-7.17 (m, 2H); 2.80 (bs, 3H)

20 <sup>13</sup>C NMR: (75.5 MHz; acetone-d<sub>6</sub>) δ (ppm): 167.2; 158.6; 146.3; 141.3; 140.9; 139.8; 139.5; 134.2; 131.0; 129.9; 129.8; 129.3; 128.7; 128.6; 128.4; 128.0; 126.8; 125.1; 122.7; 122.6; 120.1

MS: calc for C<sub>27</sub>H<sub>21</sub>O<sub>3</sub>N<sub>3</sub>S: 467.552; found: 468.5 for [M+H] (low resolution MS).



5 **Example 33:**

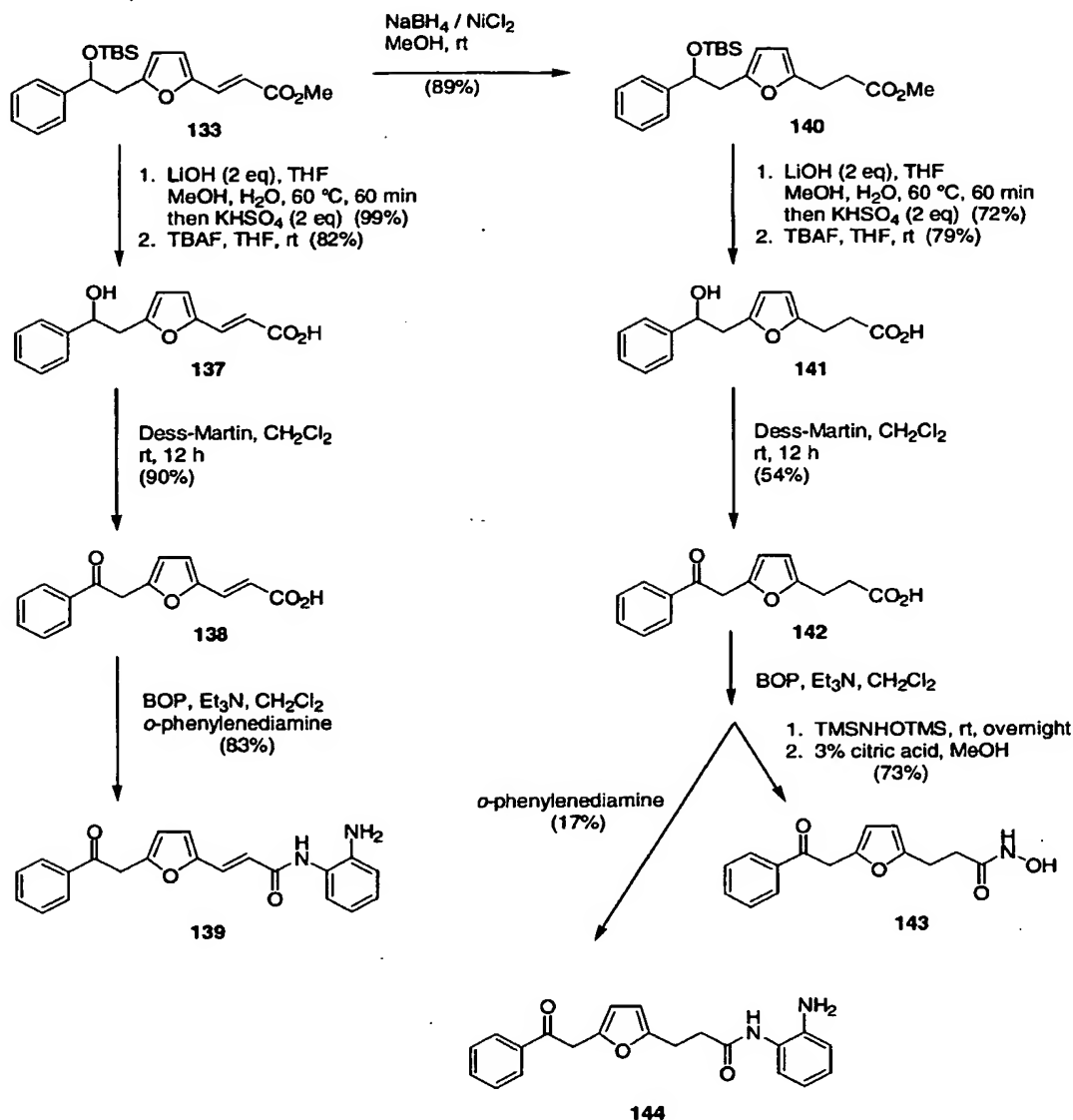
Benzylic alcohol **130** was prepared in 53 % yield by addition of 2-lithiofuran to styrene oxide. After protection of the resulting hydroxyl group with *tert*-butyldimethylsilyl chloride, the lithiated species of compound **131** was treated with DMF to afford the formyl derivative **132**. Wadsworth-Horner-Emmons olefination was effected by treatment of **132** with the sodium enolate of trimethylphosphonoacetate to afford the key intermediate **133** in 90 % overall yield for the last three steps. Saponification of the methyl ester with LiOH yielded the acid **134**, which in turn was converted into its hydroxamic acid form

- 5 135 by conventional activation with HOBt / EDC, followed by reaction with hydroxylamine. Fluoride-promoted cleavage of silylated ether gave alcohol 136 in 67 % yield.

Data for 136:

- <sup>1</sup>H NMR: (300.07 MHz; acetone-*d*6)  $\delta$  (ppm): 9.35 (bs, 1H); 7.40-7.15 (m, 6H),;  
10 6.56 (d, J=2.9 Hz, 1H); 6.24 (d, J=15.3 Hz, 1H); 4.96 (t, J=6.2 Hz, 1 H); 3.00 (d, J=6.2 Hz, 2H)

<sup>13</sup>C NMR: (75.5 MHz; CD<sub>3</sub>OD)  $\delta$  (ppm): 166.6; 156.6; 151.3; 145.2; 129.3; 128.5; 126.9; 116.2; 114.5; 111.0; 73.6; 39.1

5 **Example 34:**

Unsaturated ketoacid 138 was obtained from ester 133 in 73 % overall yield after three consecutive steps, including saponification (LiOH /  $\text{H}_2\text{O}$  / MeOH / THF), desilylation (TBAF / THF), and oxidation of benzylic alcohol 137 using Dess-Martin periodinane. Anilide 139 was obtained by BOP-mediated condensation of compound 138 with *o*-phenylenediamine in 83 % yield.

5           Regioselective hydrogenation of the acrylate moiety in **133** was accomplished by treatment with NaBH<sub>4</sub> in the presence of NiCl<sub>2</sub>, to afford the propionate **140** in high yield. Ketoacid **142** was then obtained in 31 % overall yield from **140** by an identical procedure to that followed in the synthesis of **138** from **133**. With compound **142** in hand, anilide **144** was obtained as described  
10   above (BOP / *o*-phenyldiamine). The low yield was due to a difficult purification process. To avoid oxime formation, hydroxamic acid **143** was synthesized from **142** in 73% overall yield over two steps, including BOP-mediated coupling with *N,O*-bistrimethylsilylhydroxylamine, followed by cleavage of silylated groups under acidic conditions (citric acid / MeOH).

15   Data for **139**:

<sup>1</sup>H NMR: (300.07 MHz; CDCl<sub>3</sub>) δ (ppm): 8.02-7.42 (series of multiplets, 7H); 7.34 (bs, 1H); 7.06 (m, 1H); 6.80 (d, J=7.8;1H); 6.79 (d, J=8.1;1H); 6.54 (d, J= 3.0 Hz, 1H); 6.38 (m, 1H); 6.34 (d, J= 3.0 Hz, 1H); 4.37 (s, 2H); 3.90 (bs, 2H)

<sup>13</sup>C NMR: (75.5 MHz; CDCl<sub>3</sub>) δ (ppm): 194.5; 164.4; 150.9; 150.8; 150.5; 140.5;  
20   135.9; 133.7; 128.7; 128.5; 126.9; 125.0; 124.4; 119.4; 118.0; 117.5; 115.7; 111.3; 38.5

Data for **143**:

<sup>1</sup>H NMR: (300.07 MHz; CDCl<sub>3</sub>) δ (ppm): 8.99 (bs, 1H); 8.09-7.42 (series of multiplets, 5H); 6.09 (d, J= 3.0 Hz, 1H); 6.00 (d, J= 3.0 Hz, 1H); 4.35 (s, 2H); 2.95 (t, J=6.60 Hz, 2H); 2.50 (t, J= 3.0 Hz, 1H).  
25

<sup>13</sup>C NMR: (75.5 MHz; CDCl<sub>3</sub>) δ (ppm): 196.2; 162.8; 153.2; 146.8; 134.9; 133.7; 128.7; 128.5; 109.3; 107.1; 38.2; 31.7; 24.2

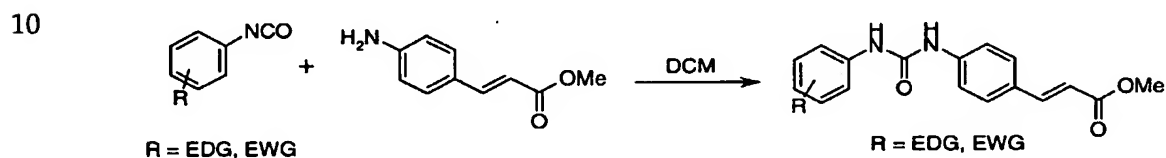
Data for **144**:

30   <sup>1</sup>H NMR: (300.07 MHz; CDCl<sub>3</sub>) δ (ppm): 7.99-7.42 (series of multiplets, 5H); 7.36 (bs, 1H); 7.02 (d, J=7.8, 2H); 6.73 (d, J= 7.8 Hz, 2H); 6.13 (d, J= 3.0 Hz, 1H); 6.04 (d, J= 3.0 Hz, 1H); 4.30 (s, 2H); 3.70 (bs, 2H); 3.03 (t, J=6.9 Hz, 2H); 2.69 (t, J= 6.9 Hz, 2H).

- 5  $^{13}\text{C}$  NMR: (75.5 MHz;  $\text{CDCl}_3$ )  $\delta$  (ppm): 195.4; 170.7; 153.6; 147.1; 140.9; 136.1; 133.5; 128.7; 128.5; 127.1; 125.7; 124.0; 119.2; 117.8; 109.1; 107.2; 38.4; 35.7; 24.7

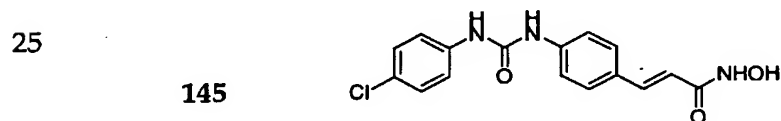
### Example 35:

#### General procedure for synthesis of urea compounds

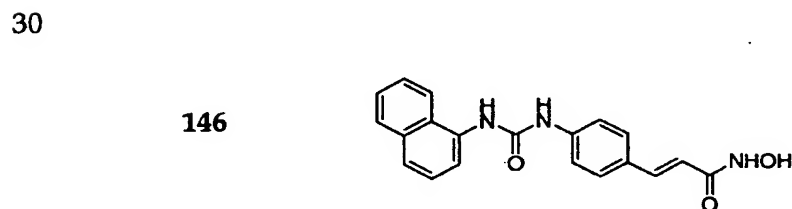


To a solution of isocyanate (1.5 mmol) in 15 mL of anhydrous  
 15 dichloromethane, was added a solution of 4-aminomethylacrylate (1.5 mmol) in  
 dichloromethane (10 mL). The mixture was stirred at room temperature for 15  
 hours. After addition of ammonium chloride solution the new mixture was  
 extracted from dichloromethane. The organic layers were combined and washed  
 with ammonium chloride solution, water, brine and dried over magnesium  
 20 sulfate. The crude was then flashed over silica gel using  $\text{CH}_2\text{Cl}_2$  : MeOH (9.5:0.5)  
 as eluent.

The following compounds were synthesized according to the general  
 procedure:



$^1\text{H}$  NMR: (300 MHz,  $\text{DMSO}-d_6$ )  $\delta$  7.5-7.7 (m, 4H, CH Ar); 7.5 (d, 2H,  $J = 6.6\text{Hz}$ );  
 7.3 (d, 2H,  $J = 6.6\text{Hz}$ ); 6.3 (d, 1H,  $J = 15\text{Hz}$ )

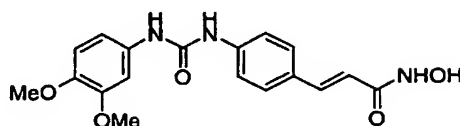


5

$^1\text{H}$  NMR: (300 MHz,  $\text{DMSO-}d_6$ )  $\delta$  7.5-8.2 (m, 7H, CH Ar); 7.5 (d, 2H,  $J = 6.6\text{Hz}$ ); 7.3 (d, 2H,  $J = 6.6\text{Hz}$ ); 6.3 (d, 1H,  $J = 15\text{Hz}$ )

10

147



$^1\text{H}$  NMR: (300 MHz,  $\text{DMSO-}d_6$ )  $\delta$  7.5-7.7 (m, 3H, CH Ar); 7.5 (d, 2H,  $J = 6.6\text{Hz}$ ); 7.3 (d, 2H,  $J = 6.6\text{Hz}$ ); 6.3 (d, 1H,  $J = 15\text{Hz}$ )

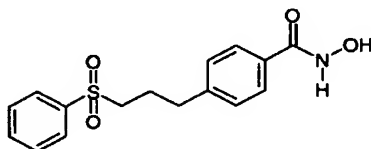
15

**Example 36:**

The following additional compounds were prepared by procedures analogous to those described in the foregoing Examples:

20

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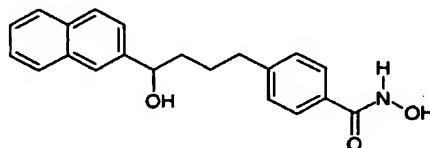
25

$^1\text{H}$  NMR (300.072 MHz,  $(\text{CD}_3)_2\text{CO}$ ):  $\delta$  1.99 (m, 2H), 2.79 (t, 2H,  $J = 7.2\text{ Hz}$ ), 3.21 (dd, 2H,  $J = 6.8, 7.8\text{ Hz}$ ), 7.27 (d, 2H,  $J = 8.1\text{ Hz}$ ), 7.65 (t, 2H,  $J = 7.8\text{ Hz}$ ), 7.72-7.77 (m, 3H), 7.90 (d, 2H,  $J = 7.2\text{ Hz}$ ), 10.77 (broad s, 1H).

$^{13}\text{C}$  NMR (75.46 MHz,  $(\text{CD}_3)_2\text{CO}$ ):  $\delta$  25.2 (t), 34.3 (t), 55.6 (t), 128.0 (d), 2 X 128.8 (d), 129.4 (d), 2 X 130.2 (d), 131.1 (s), 134.5 (d), 140.7 (s), 145.5 (s), 165.8 (s).

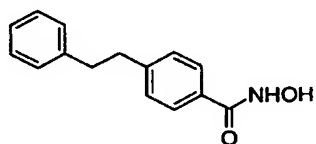
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- 5 <sup>1</sup>H NMR (300.072 MHz, (CD<sub>3</sub>)<sub>2</sub>CO): δ 1.66-1.88 (m, 4H), 2.71 (t, 2H, J = 6.3 Hz), 4.34 (d, 1H, J = 303 Hz), 4.87 (m, 1H), 7.27 (d, 2H, J = 7.8 Hz), 7.44-7.48 (m, 2H), 7.52 (dd, 1H, J = 1.5, 9.4 Hz), 7.73 (d, 2H, J = 7.8 Hz), 7.83 (s, 1H), 7.83-7.88 (m, 3H), 8.16 (broad s, 1H), 10.67 (broad s, 1H).
- <sup>13</sup>C NMR (75.46 MHz, (CD<sub>3</sub>)<sub>2</sub>CO): δ 28.3 (t), 36.2 (t), 39.8 (t), 74.0 (d), 125.0 (d),  
10 125.3 (d), 126.2 (d), 126.7 (d), 2 X 127.8 (d), 128.4 (d), 128.5 (d), 128.6 (d), 2 X 129.3 (d), 130.6 (s), 133.7 (s), 134.3 (s), 144.7 (s), 147.4 (s), 165.9(s).

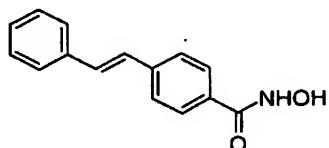
150



15

<sup>1</sup>H NMR: (300 MHz, DMSO-*d*<sub>6</sub>) δ 11.2 (s, OH); 9 (s, NH); 7.6-7.8 (m, 4H, CH Ar); 7-7.4 (m, 5H, CH Ar); 2.8 (m, 4H, CH<sub>2</sub>).

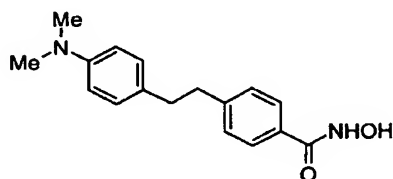
151



20

<sup>1</sup>H NMR: (300 MHz, DMSO-*d*<sub>6</sub>) δ 11.2 (s, 1H); 9.0 (s, 1H); 7.7 (m, 6H); 7.34 (m, 5H).

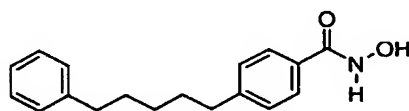
152



25

- 30 <sup>1</sup>H NMR: (300 MHz, DMSO-*d*<sub>6</sub>) δ 11.2 (s, OH); 9 (s, NH); 7.6-7.8 (m, 4H, CH Ar); 7-6.8 (m, 4H, CH Ar); 2.9 (s, 6H, 2CH<sub>3</sub>); 2.8 (m, 4H, CH<sub>2</sub>).

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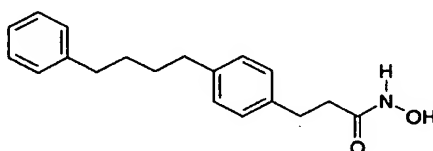


5

<sup>1</sup>H NMR (300.072 MHz, (CD<sub>3</sub>)<sub>2</sub>CO): δ 1.38 (quintuplet, 2H, J = 7.5 Hz), 1.60-1.72 (m, 4H), 2.60 (t, 2H, J = 7.8 Hz), 2.67 (t, 2H, J = 7.5 Hz), 7.15-7.31 (m, 7H), 7.75 (d, 2H, J = 8.1 Hz), 8.11 (broad s, 1H), 10.68 (broad s, 1H).

<sup>13</sup>C NMR (75.46 MHz, (CD<sub>3</sub>)<sub>2</sub>CO): δ 31.8 (t), 32.1 (t), 36.2 (t), 36.4 (t), 126.4 (d),  
10 127.8 (d), 2 X 129.0 (d), 2 X 129.2 (d), 2 X 129.3 (d), 143.3 (s).

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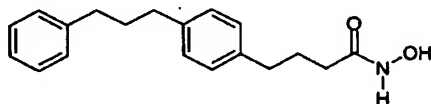


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<sup>1</sup>H NMR (300.072 MHz, (CD<sub>3</sub>)<sub>2</sub>CO): δ 1.63 (m, 4H, J = 4.5 Hz), 2.37 (t, 2H, J = 7.8 Hz), 2.57-2.66 (m, 4H), 2.86 (t, 2H, J = 7.5 Hz), 7.10-7.28 (m, 9H), 8.01 (broad s, 1H), 9.98 (broad s, 1H).

<sup>13</sup>C NMR (75.46 MHz, (CD<sub>3</sub>)<sub>2</sub>CO): δ 31.0 (t), 2 X 31.9 (t), 35.1 (t), 35.8 (t), 36.2 (t),  
20 126.4 (d), 2 X 129.0 (d), 2 X 129.1 (d), 2 X 129.1 (d), 129.2 (d), 138.8 (s), 141.2 (s),  
143.4 (s), 164.1 (s).

155

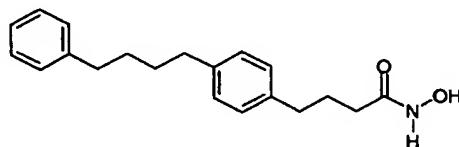


25

<sup>1</sup>H NMR (300.072 MHz, (CD<sub>3</sub>)<sub>2</sub>CO): δ 1.83-1.98 (m, 4H), 2.08-2.14 (m, 2H), 2.56-2.67 (m, 6H), 7.12-7.30 (m, 9H), 9.98 (broad s, 1H).

30

156

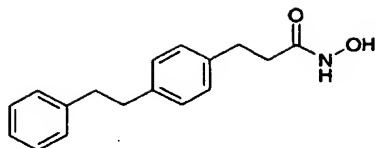


<sup>1</sup>H NMR (300.072 MHz, (CD<sub>3</sub>)<sub>2</sub>CO): δ 1.60-1.68 (m, 4H), 1.87 (quintuplet, 2H, J = 7.5 Hz), 2.03-2.14 (m, 2H), 2.55-2.67 (m, 6H), 7.09-7.28 (m, 9H).



5

157

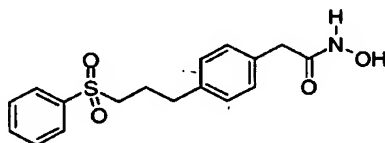


10  $^1\text{H}$  NMR (300.072 MHz,  $(\text{CD}_3)_2\text{CO}$ ):  $\delta$  2.37 (t, 2H,  $J = 7.2$  Hz), 2.78-2.89 (m, 6H), 7.13-7.29 (m, 9H), 7.84 (broad s, 1H), 9.90 (broad s, 1H).

$^{13}\text{C}$  NMR (75.46 MHz,  $(\text{CD}_3)_2\text{CO}$ ):  $\delta$  31.6 (t), 35.1 (t), 38.2 (t), 38.6 (t), 2 X 126.6 (d), 2 X 129.1 (d), 2 X 129.2 (d), 2 X 129.3 (d), 139.4 (s), 140.4 (s), 142.8 (s), 170.1 (s).

15

158

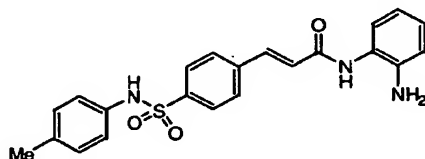


20  $^1\text{H}$  NMR (300.072 MHz,  $(\text{CD}_3)_2\text{CO}$ ):  $\delta$  1.96 (quintuplet, 2H,  $J = 6.0$  Hz), 2.69 (t, 2H,  $J = 8.0$  Hz), 3.19 (dd, 2H,  $J = 6.0, 9.0$  Hz), 3.38 (s, 2H), 7.09 (d, 2H,  $J = 7.5$  Hz), 7.21 (d, 2H,  $J = 7.5$  Hz), 7.66 (t, 2H,  $J = 8.1$  Hz), 7.747 (t, 1H,  $J = 6.9$  Hz), 7.90 (d, 2H,  $J = 6.6$  Hz), 10.08 (broad s, 1H).

$^{13}\text{C}$  NMR (75.46 MHz,  $(\text{CD}_3)_2\text{CO}$ ):  $\delta$  25.5 (t), 34.1 (t), 39.9 (t), 55.7 (t), 2 X 128.8 (d), 130.0 (d), 2 X 130.2 (d), 134.4 (s), 139.9 (s), 140.7 (s), 168.5 (s).

25

159

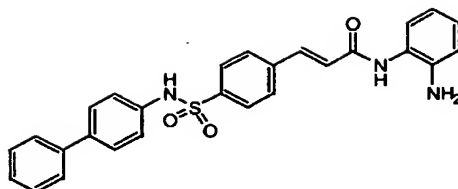


30  $^1\text{H}$  NMR: (300 MHz, DMSO  $d_6$ ):  $\delta$  7.77 (broad s, 4H); 7.57 (d, 1H,  $J = 15.7$  Hz); 7.35 (d, 1H,  $J = 6.9$  Hz); 7.03-6.94 (m, 6H); 6.76 (d, 1H,  $J = 7.1$  Hz); 6.59 (d, 1H,  $J = 6.9$  Hz); 4.98 (broad s, 2H); 2.19 (s, 3H).

$^{13}\text{C}$  NMR: (75 MHz, DMSO  $d_6$ ):  $\delta$  162.9; 141.6; 139.8; 139.0; 137.6; 134.8; 133.6; 129.6; 128.1; 127.3; 125.9; 125.4; 124.7; 123.2; 120.7; 116.2; 115.9; 20.3.

5

160

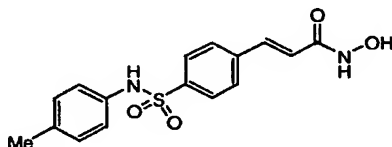


10

$^1\text{H}$  NMR: (300 MHz, DMSO  $d_6$ ):  $\delta$  7.91-7.81 (m, 4H); 7.63-7.58 (m, 5H); 7.48-7.43 (m, 2H); 7.39-7.33 (m, 2H); 7.24 (d, 2H,  $J=8.5$  Hz); 6.97 (dd, 2H,  $J=9.9, 7.1$  Hz); 6.79 (d, 1H,  $J=7.7$  Hz); 6.61 (dd, 1H,  $J=7.7, 7.1$  Hz); 5.01 (broad s, 2H).

$^{13}\text{C}$  NMR: (75 MHz, DMSO  $d_6$ ):  $\delta$  162.9; 141.9; 141.6; 139.8; 139.2; 137.6; 136.9; 135.8; 128.9; 128.3; 127.4; 127.3; 127.2; 126.3; 126.0; 125.5; 124.8; 123.2; 120.4; 116.2; 115.9.

161

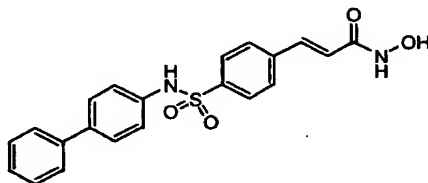


20

$^1\text{H}$  NMR: (300 MHz, MeOD  $d_4$ ):  $\delta$  7.74-7.54 (m, 5H); 7.07-6.96 (m, 4H); 6.55 (d, 1H,  $J=15.7$ ); 2.25 (s, 3H).

$^{13}\text{C}$  NMR: (75 MHz, MeOD  $d_4$ ):  $\delta$  163.5; 141.6; 140.4; 139.5; 136.1; 135.9; 130.6; 129.0; 128.8; 123.1; 121.7; 20.8

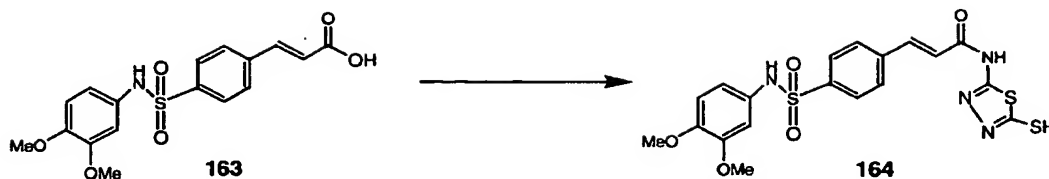
162



30

$^1\text{H}$  NMR: (300 MHz, MeOD  $d_4$ ):  $\delta$  7.83-7.19 (m, 14H); 6.56 (d, 1H,  $J=15.7$  Hz).

$^{13}\text{C}$  NMR: (75 MHz, MeOD  $d_4$ ):  $\delta$  165.4; 141.6; 141.4; 140.5; 139.5; 139.0; 137.9; 129.8; 129.2; 128.7; 128.6; 128.2; 127.6; 122.7; 121.7.

5 **Example 37:**

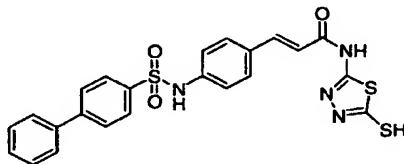
To a solution of carboxylic acid **163** (131 mg, 0.36 mmol), prepared according to procedures described above, in 6 mL of dry DMF was added Et<sub>3</sub>N (190  $\mu$ L, 1.37 mmol), followed by the addition of solid BOP (259 mg; 0.59 mmol). The reaction mixture was stirred for 10 min. at room temperature and then solid 5-amino-1,3,4-thiadiazole-2-thiol (58 mg, 0.43 mmol) was added. After being stirred for 12 h, the mixture was diluted with methanol and concentrated under vacuum. Upon dilution with CH<sub>2</sub>Cl<sub>2</sub> / MeOH, crystallization of **164** (150 mg, 87%) from the crude oil took place.

<sup>1</sup>H NMR: (300 MHz, DMSO *d*<sub>6</sub>):  $\delta$  7.85 (broad s, 5H); 7.04-6.58 (m, 4H); 3.69 (s, 3H); 3.67 (s, 3H); 3.38 (broad s, 3H).

<sup>13</sup>C NMR: (75 MHz, DMSO *d*<sub>6</sub>): 163.3; 161.7; 158.7; 148.7; 146.2; 142.0; 140.7; 137.9; 130.1; 128.7; 127.5; 121.4; 113.7; 112.0; 106.6; 55.5; 55.4.

Following this general procedure, the following thiadiazole derivatives were prepared from the corresponding carboxylic acids:

25

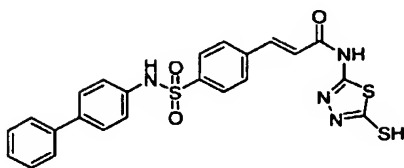
**165**

<sup>1</sup>H NMR: (300 MHz, DMSO-*d*<sub>6</sub>);  $\delta$  (ppm): 7.89-7.72 (series of multiplets, 7H); 7.50-7.05 (series of multiplets, 6H); 3.32 (broad singlet, 3H)

<sup>13</sup>C NMR: (75 MHz, DMSO-*d*<sub>6</sub>);  $\delta$  (ppm): 162.6; 162.3; 144.5; 138.3; 138.3; 138.2; 132.5; 130.1; 129.7; 129.1; 128.6; 127.6; 127.3; 127.1; 120.9; 118.7; 116.8.

5 MS: calc. for M+H: 493.6. obs. for M+H: 496.3

166



10

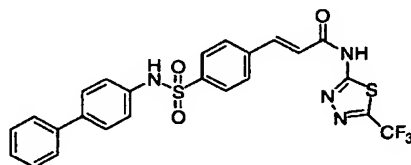
<sup>1</sup>H NMR: (300 MHz, DMSO *d*<sub>6</sub>): 7.87-7.72 (m, 5 H), 7.57-7.53 (m, 4 H), 7.39 (dd, 2 H, J = 6.9, 7.7 Hz), 7.30 (d, 1 H, J = 7.1 Hz), 7.17 (d, 2 H, J = 8.5 Hz), 6.85 (d, 1 H, J = 15.9 Hz).

15 MS: cal: 495.61; found: 496.6

Following an analogous procedure, but substituting 2-amino-5-trifluoromethyl-1,3,4-thiadiazole for 5-amino-1,3,4-thiadiazol-2-thiol, the following compound was prepared:

20

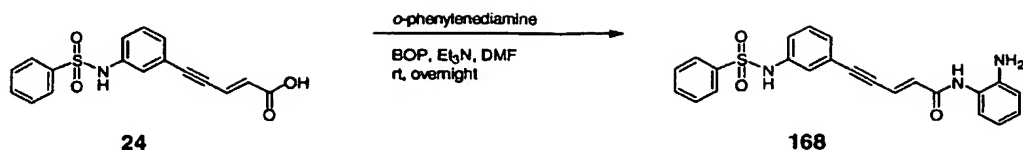
167



25 <sup>1</sup>H NMR: (300 MHz, DMSO *d*<sub>6</sub>): δ 7.96-7.81 (m, 5H); 7.71-7.48 (m, 4H); 7.38 (dd, 2H, J=7.1, 7.41 Hz); 7.28 (d, 1H, J= 7.1 Hz); 7.19 (d, 2H, J= 8.5 Hz); 6.98 (d, 1H, J=15.7 Hz).

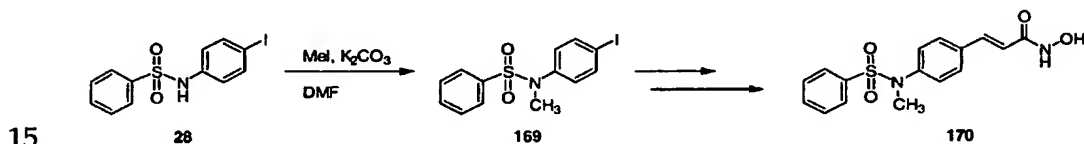
<sup>13</sup>C NMR: (75 MHz, DMSO *d*<sub>6</sub>): 192.3; 163.6; 161.6; 142.4; 140.9; 139.2; 138.0; 136.8; 135.9; 129.0; 128.8; 127.4; 127.2; 126.2; 121.2; 120.4.

30 MS: cal: 530.55 found: 531.5

5 **Example 38:**

Coupling of 24 (from Example 15) with *o*-phenylenediamine in the presence of benzotriazol-1-yloxytris(dimethylamino)phosphonium hexafluorophosphate (BOP) afforded the anilide 168.

By an analogous procedure, the corresponding *para*-substituted compound is prepared from 32 (from Example 16).

**Example 39:****Step 1: N-Methyl-4-iodophenylbenzenesulfonamide (169)**

To compound 28 (from Example 18) (500 mg, 1.39 mmol) in DMF (10 mL) were added at room temperature K<sub>2</sub>CO<sub>3</sub> (962 mg, 6.96 mmol), followed by methyl iodide (395 mg, 2.78 mmol). The resulting reaction mixture was stirred at room temperature for 16 hours. The solvent is then removed and water was added. The resulting mixture was extracted with ethyl acetate, and the combined organic phases were dried and concentrated. Purification by flash chromatography using hexane:ethyl acetate (8:2) afforded 510 mg (98%) of the title compound as a white solid.

Compound 169 was converted to the hydroxamic acid 170 according to the procedures described in Example 18 for the preparation of compound 36.

Data for 170:

5 <sup>1</sup>H NMR: (300 MHz, DMSO d<sub>6</sub>): δ = 10.76 (1H, s), 9.04 (1H, s), 7.73-7.68 (1H, m),  
7.61-7.51 (6H, m), 7.43 (1H, d, J = 15.9 Hz), 7.15 (2H, d, J = 8.7 Hz), 6.43 (1H, d, J =  
16.2 Hz), 3.15 (3H, s).

Analysis: C<sub>16</sub>H<sub>16</sub>N<sub>2</sub>O<sub>4</sub>S X 0.5 H<sub>2</sub>O Found: C=56.36%, H=5.09%, N=8.69%, S=8.33%.  
Calc.: C=56.29%, H=5.02%, N=8.21%, S=9.39%.

10

#### **Example 40:**

##### **Inhibition of Histone Deacetylase Enzymatic Activity**

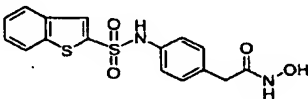
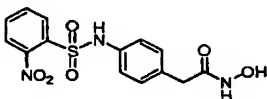
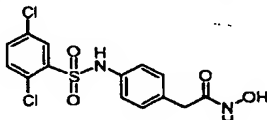
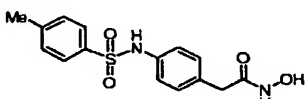
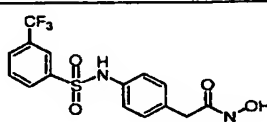
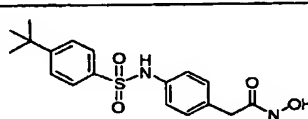
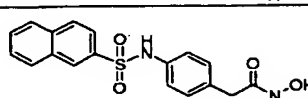
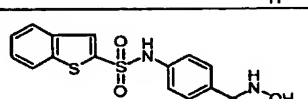
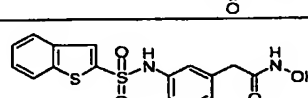
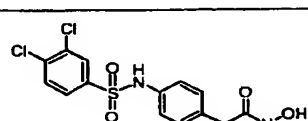
HDAC inhibitors were screened against histone deacetylase enzyme in  
nuclear extracts prepared from the human small cell lung cancer cell line H446  
15 (ATTC HTB-171) and against a cloned recombinant human HDAC-1 enzyme  
expressed and purified from a Baculovirus insect cell expression system.

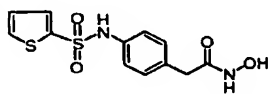
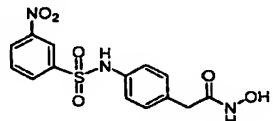
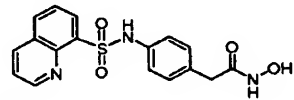
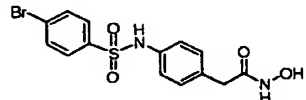
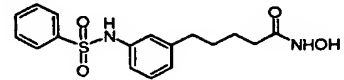
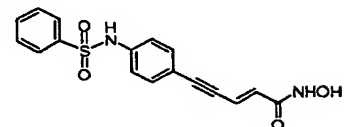
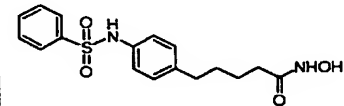
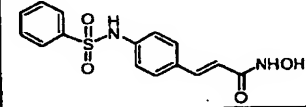
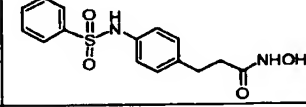
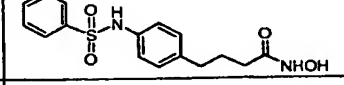
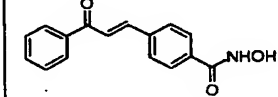
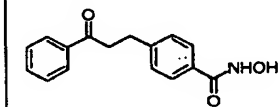
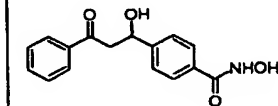
For deacetylase assays, 20,000 cpm of the [<sup>3</sup>H]-metabolically labeled  
acetylated histone substrate (M. Yoshida *et al.*, *J. Biol. Chem.* 265(28): 17174-17179  
(1990)) was incubated with 30 µg of H446 nuclear extract or an equivalent  
20 amount of the cloned recombinant hHDAC-1 for 10 minutes at 37 °C. The  
reaction was stopped by adding acetic acid (0.04 M, final concentration) and HCl  
(250 mM, final concentration). The mixture was extracted with ethyl acetate and  
the released [<sup>3</sup>H]-acetic acid was quantified by scintillation counting. For  
inhibition studies, the enzyme was preincubated with compounds at 4 °C for 30  
25 minutes prior to initiation of the enzymatic assay. IC<sub>50</sub> values for HDAC enzyme  
inhibitors were determined by performing dose response curves with individual  
compounds and determining the concentration of inhibitor producing fifty  
percent of the maximal inhibition.

Representative data are presented in Table 4. In the first column are  
30 reported IC<sub>50</sub> values determined against histone deacetylase in nuclear extracts  
from H446 cells (pooled HDACs). In the second column are reported IC<sub>50</sub> values  
determined against recombinant human HDAC-1 enzyme (rHDAC-1). For less

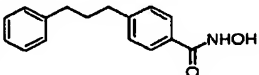
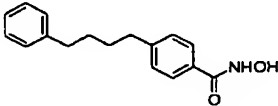
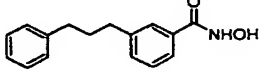
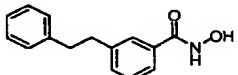
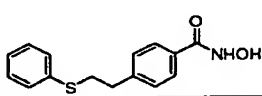
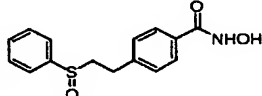
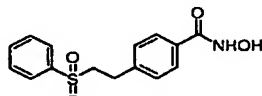
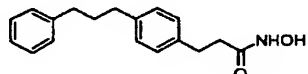
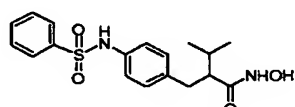
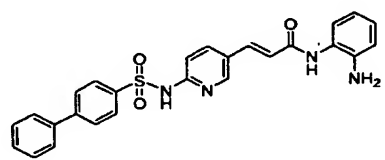
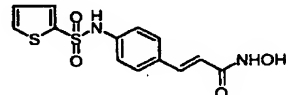
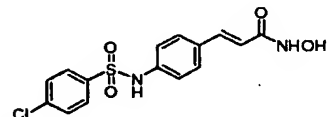
- 5 active compounds, the data are expressed as the percent inhibition at the specified concentration.

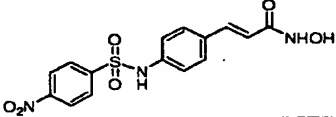
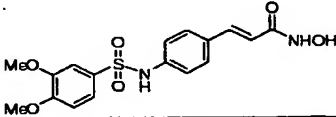
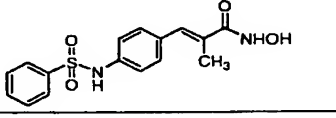
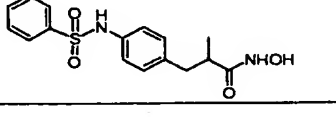
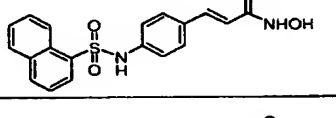
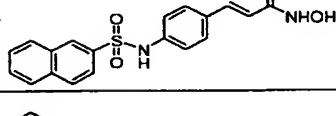
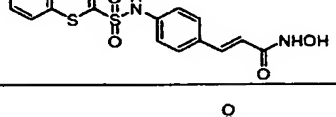
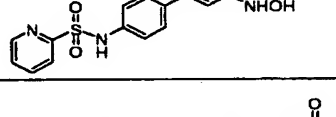
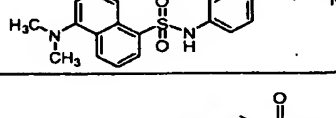
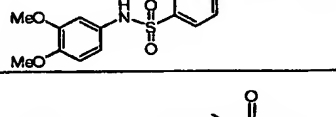
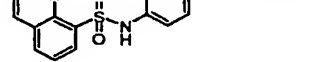
**Table 4: Inhibition of Histone Deacetylase**

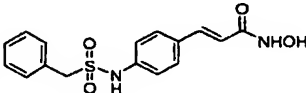
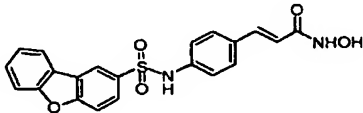
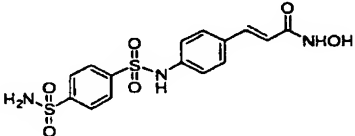
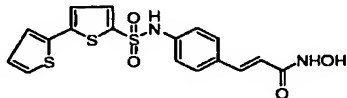
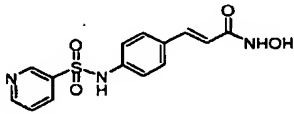
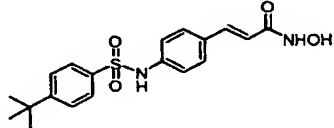
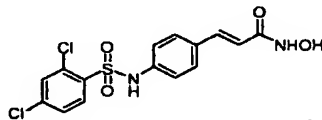
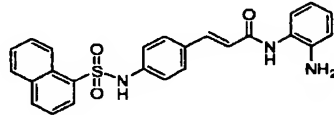
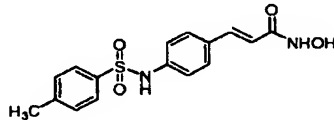
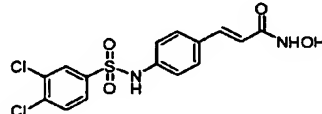
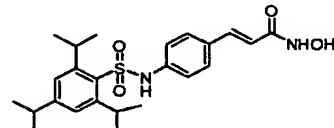
Example	Cpd.	Structure	pooled HDACs IC <sub>50</sub> (μM)	rHDAC-1 IC <sub>50</sub> (μM)
Ex. 1	4		7	
Ex. 2	7		70	
Ex. 3	8		15	
Ex. 4	9		9	
Ex. 5	10		30	
Ex. 6	11		10	
Ex. 7	12		3	
Ex. 8	13		0.9	
Ex. 9	14		36% @ 100 μM	
Ex. 10	15		25	

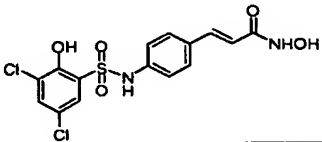
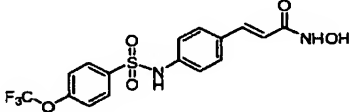
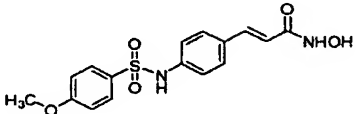
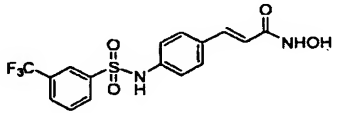
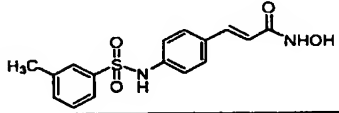
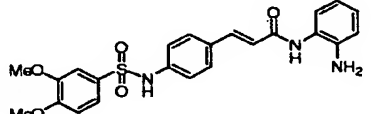
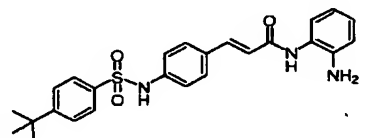
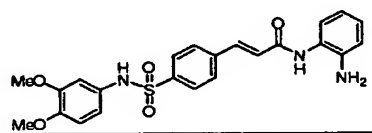
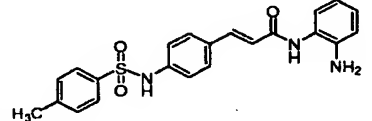
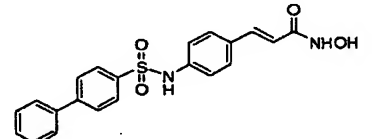
Ex. 11	16		38% 100 $\mu$ M	
Ex. 12	17		47% 100 $\mu$ M	
Ex. 13	18		160	
Ex. 14	19		20	
Ex. 15	26		< 20	
Ex. 16	32		< 20	
Ex. 17	34		2	0.3
Ex. 18	36		0.5	0.2
Ex. 19	38		0.75	0.1
Ex. 20	42		5	1.0
Ex. 21	45		4	
Ex. 22	50		5	
Ex. 23	53		25	

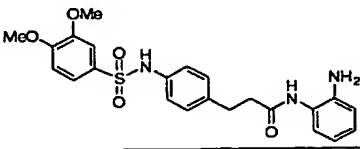
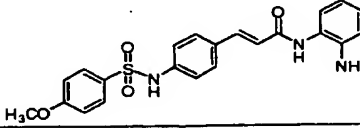
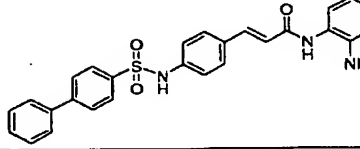
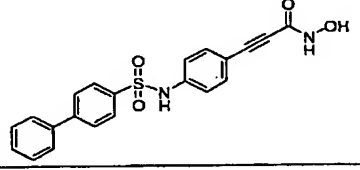
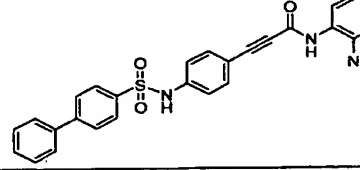
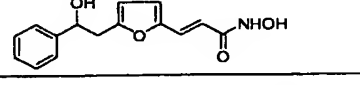
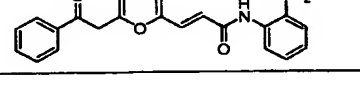
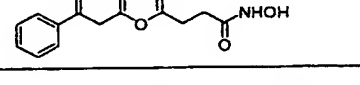
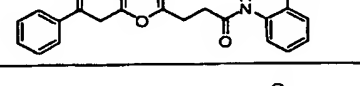
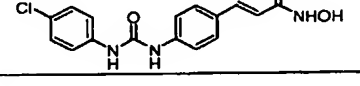
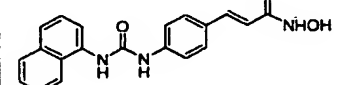


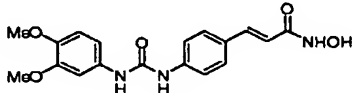
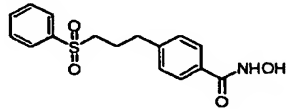
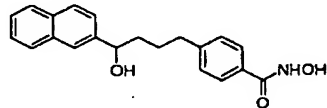
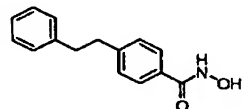
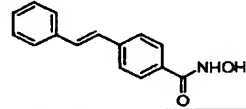
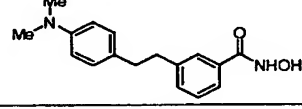

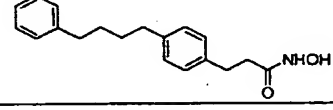
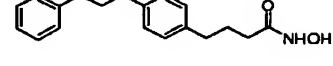
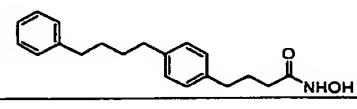
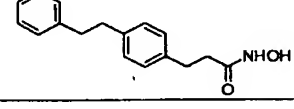
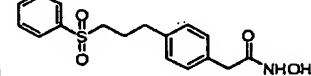
Ex. 24	56		15	
Ex. 25	61		4	
Ex. 26	64		12% @ 100 $\mu$ M	
Ex. 27	68		3% @ 20 $\mu$ M	
Ex. 28	70		5.5	0.9
Ex. 28	71		44% @ 20 $\mu$ M	
Ex. 28	73		35% @ 20 $\mu$ M	
Ex. 29	77		3	0.65
Ex. 30	81		> 50	> 25
Ex. 31	86			3.8
Ex. 31	87		3	0.6
Ex. 31	88		0.6	0.075

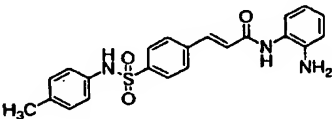
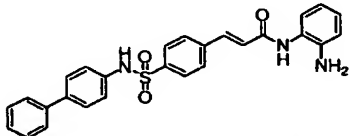
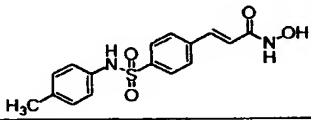
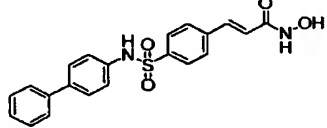
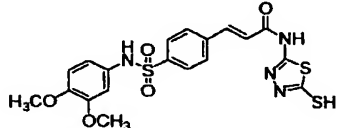
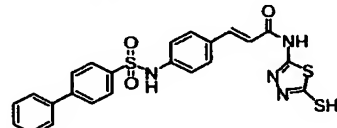
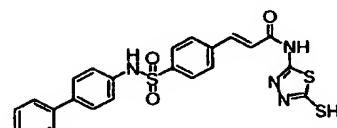
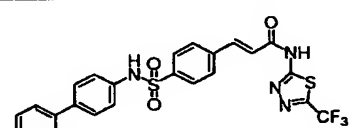
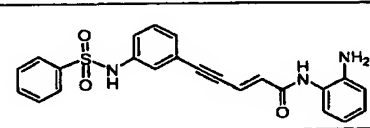
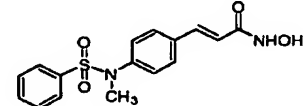
Ex. 31	89		3	0.9
Ex. 31	90		0.4	0.09
Ex. 31	91		5	2
Ex. 31	92		> 20	17
Ex. 31	93		0.35	0.05
Ex. 31	94		0.4	0.03
Ex. 31	95		0.8	0.2
Ex. 31	96		33% @ 5 $\mu$ M	
Ex. 31	97		0.8	0.28
Ex. 31	98		0.55	0.06
Ex. 31	99		0.9	0.05

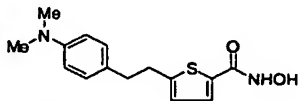
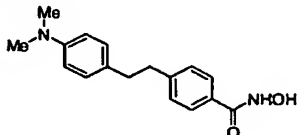
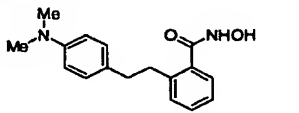
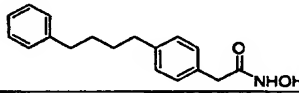
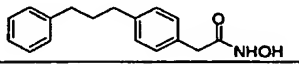
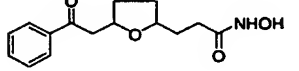
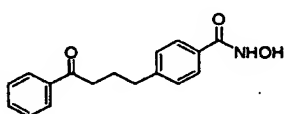
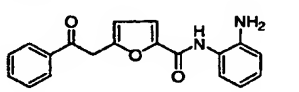
Ex. 31	100		0.8	0.75
Ex. 31	101		0.3	0.04
Ex. 31	102		5.5	0.8
Ex. 31	103		0.7	0.05
Ex. 31	104		21% @ 5 $\mu$ M	
Ex. 31	105		0.55	0.2
Ex. 31	106		0.8	0.3
Ex. 31	107		0% @ 1 $\mu$ M	5
Ex. 31	108		10% @ 1 $\mu$ M	0.3
Ex. 31	109		32% @ 1 $\mu$ M	0.12
Ex. 31	110		0.7	0.55

Ex. 31	111		0.4	0.095
Ex. 31	112		1.2	0.6
Ex. 31	113		46% @ 1 $\mu$ M	0.2
Ex. 31	114		40% @ 1 $\mu$ M	0.1
Ex. 31	115		53% @ 1 $\mu$ M	0.1
Ex. 31	116			4
Ex. 31	117		0% @ 20 $\mu$ M	1.9
Ex. 31	118		0% @ 20 $\mu$ M	2.3
Ex. 31	119			3
Ex. 31	120		0.12	0.01

Ex. 31	121			23
Ex. 31	122			2.3
Ex. 31	123			1
Ex. 32	128			0.3
Ex. 32	129			3.0
Ex. 33	136		9	0.5
Ex. 34	139		44% @ 20 μM	
Ex. 34	143		55% @ 20 μM	2.4
Ex. 34	144		6% @ 20 μM	6.9
Ex. 35	145		3.8	0.84
Ex. 35	146		2.9	0.91

Ex. 35	147		1.9	0.48
Ex. 36	148		5	2.0
Ex. 36	149		8% @ 20 $\mu$ M	0.1
Ex. 36	150		10	1.0
Ex. 36	151		7.5	2.3
Ex. 36	152		35% @ 20 $\mu$ M	
Ex. 36	153		5	4.8
Ex. 36	154		2	0.9
Ex. 36	155		39% @ 20 $\mu$ M	
Ex. 36	156		5	0.75
Ex. 36	157		6	2.4
Ex. 36	158		> 20	

Ex. 36	159			1.5
Ex. 36	160			1.2
Ex. 36	161			0.05
Ex. 36	162			0.04
Ex. 37	164			5.0
Ex. 37	165			2.0
Ex. 37	166			
Ex. 37	167			
Ex. 38	168		0% @ 20 $\mu$ M	3
Ex. 39	170		48% @ 2 $\mu$ M	0.57

	171		20	
	172		10	
	173		35% @ 20 $\mu$ M	
	174		> 20	
	175		> 20	
	176		20% @ 20 $\mu$ M	
	177		10% @ 20 $\mu$ M	
	178		2% @ 20 $\mu$ M	>20

5

**Example 41:****Inhibition of Histone Deacetylase in Whole Cells****1. Histone H4 acetylation in whole cells by immunoblots**

- 10 T24 human bladder cancer cells growing in culture were incubated with HDAC inhibitors for 16 hours. Histones were extracted from the cells after the culture period as described by M. Yoshida *et al.* (*J. Biol. Chem.* 265(28): 17174-17179 (1990)). 20  $\mu$ g of total histone protein was loaded onto SDS/PAGE and transferred to nitrocellulose membranes. Membranes were probed with
- 15 polyclonal antibodies specific for acetylated histone H-4 (Upstate Biotech Inc.), followed by horse radish peroxidase conjugated secondary antibodies (Sigma).

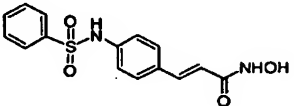
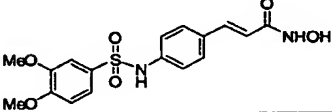
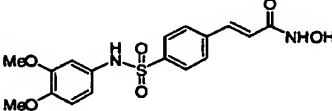
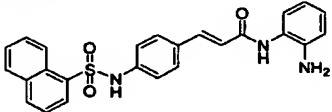
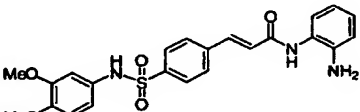
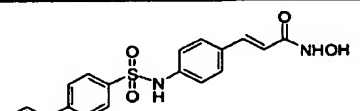
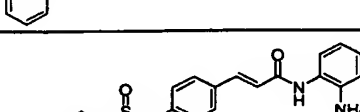


- 5 Enhanced Chemiluminescence (ECL) (Amersham) detection was performed using Kodak films (Eastman Kodak). Acetylated H-4 signal was quantified by densitometry.

Data for selected compounds are presented in Table 5. Data are presented as the concentration effective for reducing the acetylated H-4 signal by 50%

10 ( $EC_{50}$ ).

**Table 5: Inhibition of Histone Acetylation in Cells**

Cpd.	Structure	$EC_{50}$ ( $\mu$ M)
36		5
90		1
98		1
107		5
118		3
120		1
122		2

5     2.     Acid Urea Triton (AUT) gel analysis of histone acetylation.

Human cancer cells (T24, 293T or Jurkat cells) growing in culture are incubated with HDAC inhibitors for 24 h. Histones are extracted from the cells as described by M. Yoshida *et al.* (*J. Biol. Chem.* 265(28): 17174-17179 (1990)). Acid urea triton (AUT) gel electrophoresis is used for detection of acetylated histone molecules. Histones (150 µg of total protein) are electrophoresed at 80 V for 16 h at room temperature as described by M. Yoshida *et al., supra.* Gels are stained with Coomassie brilliant blue to visualize histones, dried and scanned by densitometry to quantified acetylation of histones.

15     Example 42:

**Antineoplastic Effect of Histone Deacetylase Inhibitors on Tumor Cells *In Vivo***

Eight to ten week old female BALB/c nude mice (Taconic Labs, Great Barrington, NY) are injected subcutaneously in the flank area with  $2 \times 10^6$  preconditioned A549 human lung carcinoma cells. Preconditioning of these cells is done by a minimum of three consecutive tumor transplantations in the same strain of nude mice. Subsequently, tumor fragments of approximately 30 mgs are excised and implanted subcutaneously in mice, in the left flank area, under Forene anesthesia (Abbott Labs, Geneve, Switzerland). When the tumors reach a mean volume of 100 mm<sup>3</sup>, the mice are treated intravenously, subcutaneously, or intraperitoneally by daily injection, with a solution of the histone deacetylase inhibitor in an appropriate vehicle, such as PBS, DMSO/water, or Tween 80/water, at a starting dose of 10 mg/kg. The optimal dose of the HDAC inhibitor is established by dose response experiments according to standard protocols. Tumor volume is calculated every second day post infusion according to standard methods (*e.g., Meyer et al., Int. J. Cancer* 43: 851-856 (1989)). Treatment with the HDAC inhibitors according to the invention causes a significant reduction in tumor weight and volume relative to controls treated with saline only (*i.e., no HDAC inhibitor*). In addition, the activity of histone

- 5 deacetylase when measured is expected to be significantly reduced relative to saline treated controls.

**Example 43:**

10 **Synergistic Antineoplastic Effect of Histone Deacetylase Inhibitors and Histone Deacetylase Antisense Oligonucleotides on Tumor Cells *In Vivo***

- The purpose of this example is to illustrate the ability of the histone deacetylase inhibitor of the invention and a histone deacetylase antisense oligonucleotide to synergistically inhibit tumor growth in a mammal. Preferably, the antisense oligonucleotide and the HDAC inhibitor inhibit the
- 15 expression and activity of the same histone deacetylase.

- As described in Example 10, mice bearing implanted A549 tumors (mean volume 100 mm<sup>3</sup>) are treated daily with saline preparations containing from about 0.1 mg to about 30 mg per kg body weight of histone deacetylase antisense oligonucleotide. A second group of mice is treated daily with pharmaceutically
- 20 acceptable preparations containing from about 0.01 mg to about 5 mg per kg body weight of HDAC inhibitor.

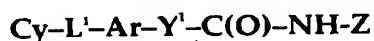
- Some mice receive both the antisense oligonucleotide and the HDAC inhibitor. Of these mice, one group may receive the antisense oligonucleotide and the HDAC inhibitor simultaneously intravenously via the tail vein. Another
- 25 group may receive the antisense oligonucleotide via the tail vein, and the HDAC inhibitor subcutaneously. Yet another group may receive both the antisense oligonucleotide and the HDAC inhibitor subcutaneously. Control groups of mice are similarly established which receive no treatment (*e.g.*, saline only), a mismatch antisense oligonucleotide only, a control compound that does not
- 30 inhibit histone deacetylase activity, and a mismatch antisense oligonucleotide with a control compound.

Tumor volume is measured with calipers. Treatment with the antisense oligonucleotide plus the histone deacetylase protein inhibitor according to the

- 5 invention causes a significant reduction in tumor weight and volume relative to controls.

5 What is claimed is:

1. An inhibitor of histone deacetylase represented by the formula



wherein

Cy is cycloalkyl, aryl, heteroaryl, or heterocyclyl, any of which may be  
10 optionally substituted;

L<sup>1</sup> is  $-(\text{CH}_2)_m\text{-W-}$ , where m is 0, 1, 2, 3, or 4, and W is selected from the group consisting of  $-\text{C(O)NH-}$ ,  $-\text{S(O)}_2\text{NH-}$ ,  $-\text{NHC(O)-}$ ,  $-\text{NHS(O)}_2\text{-}$ , and  $-\text{NH-C(O)-NH-}$ ;

Ar is arylene, wherein said arylene optionally may be additionally  
15 substituted and optionally may be fused to an aryl or heteroaryl ring, or to a saturated or partially unsaturated cycloalkyl or heterocyclic ring, any of which may be optionally substituted;

Y<sup>1</sup> is a chemical bond or a straight- or branched-chain saturated alkylene, wherein said alkylene may be optionally substituted; and

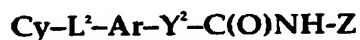
20 Z is selected from the group consisting of aniliny, pyridyl, thiadiazolyl, and  $-\text{O-M}$ , M being H or a pharmaceutically acceptable cation;

provided that when L<sup>1</sup> is  $-\text{C(O)NH-}$ , Y is  $-(\text{CH}_2)_n\text{-}$ , n being 1, 2, or 3, and Z is  $-\text{O-M}$ , then Cy is not aminophenyl, dimethylaminophenyl, or hydroxyphenyl; and further provided that when L<sup>1</sup> is  $-\text{C(O)NH-}$  and Z is pyridyl, then Cy is not  
25 substituted indoliny.

2. The inhibitor of claim 1, wherein Z is selected from the group consisting of 2-aniliny, 2-pyridyl, 1,3,4-thiadiazol-2-yl, and  $-\text{O-M}$ , M being H or a pharmaceutically acceptable cation.

3. The inhibitor of claim 2, wherein Z is 1,3,4-thiadiazol-2-yl which is  
30 substituted at the 5-position with a substituent selected from the group consisting of thiol, trifluoromethyl, amino, and sulfonamido.

- 5           4.     The inhibitor of claim 1, wherein Y<sup>1</sup> is C<sub>1</sub>-C<sub>4</sub> alkylene.
5.     The inhibitor of claim 1, wherein Y<sup>1</sup> is C<sub>1</sub>-C<sub>3</sub> alkylene.
6.     The inhibitor of claim 1, wherein Ar is substituted or unsubstituted  
phenylene, which optionally may be fused to an aryl or heteroaryl ring, or to a  
saturated or partially unsaturated cycloalkyl or heterocyclic ring, any of which  
10    may be optionally substituted.
7.     The inhibitor of claim 6, wherein the phenylene is 4-phenylene.
8.     The inhibitor of claim 1, wherein Cy is selected from the group  
consisting of phenyl, naphthyl, thienyl, benzothienyl, and quinolyl, any of which  
may be optionally substituted.
- 15           9.     The inhibitor of claim 8, wherein the phenyl, naphthyl, thienyl,  
benzothienyl, or quinolyl is unsubstituted or is substituted by one or two  
substituents independently selected from the group consisting of C<sub>1</sub>-C<sub>4</sub> alkyl, C<sub>1</sub>-  
C<sub>4</sub> haloalkyl, C<sub>6</sub>-C<sub>10</sub> aryl, (C<sub>6</sub>-C<sub>10</sub>)ar(C<sub>1</sub>-C<sub>4</sub>)alkyl, halo, nitro, hydroxy, C<sub>1</sub>-C<sub>4</sub> alkoxy,  
C<sub>1</sub>-C<sub>4</sub> alkoxycarbonyl, carboxy, and amino.
- 20           10.    The inhibitor of claim 1, wherein m is zero.
11.    An inhibitor of histone deacetylase represented by the formula



wherein

- Cy is cycloalkyl, aryl, heteroaryl, or heterocyclyl, any of which may be  
25    optionally substituted, provided that Cy is not a (spirocycloalkyl)heterocyclyl;  
            L<sup>2</sup> is C<sub>1</sub>-C<sub>4</sub> saturated alkylene or C<sub>2</sub>-C<sub>4</sub> alkenylene, wherein the alkylene or  
alkenylene optionally may be substituted, provided that L<sup>2</sup> is not -C(O)-, and  
wherein one of the carbon atoms of the alkylene optionally may be replaced by a

- 5 heteroatom moiety selected from the group consisting of O; NR', R' being alkyl, acyl, or hydrogen; S; S(O); or S(O)<sub>2</sub>;

Ar is arylene, wherein said arylene optionally may be additionally substituted and optionally may be fused to an aryl or heteroaryl ring, or to a saturated or partially unsaturated cycloalkyl or heterocyclic ring, any of which  
10 may be optionally substituted; and

Y<sup>2</sup> is a chemical bond or a straight- or branched-chain saturated alkylene, which may be optionally substituted, provided that the alkylene is not substituted with a substituent of the formula -C(O)R wherein R comprises an α-amino acyl moiety; and

- 15 Z is selected from the group consisting of aniliny, pyridyl, thiadiazolyl, and -O-M, M being H or a pharmaceutically acceptable cation;

provided that when the carbon atom to which Cy is attached is oxo substituted, then Cy and Z are not both pyridyl.

- 20 12. The inhibitor of claim 11, wherein Z is selected from the group consisting of 2-aniliny, 2-pyridyl, 1,3,4-thiadiazol-2-yl, and -O-M, M being H or a pharmaceutically acceptable cation.

13. The inhibitor of claim 12, wherein Z is 1,3,4-thiadiazol-2-yl which is substituted at the 5-position with a substituent selected from the group consisting of thiol, trifluoromethyl, amino, and sulfonamido.

- 25 14. The inhibitor of claim 11, wherein Y<sup>2</sup> is a chemical bond.

15. The inhibitor of claim 11, wherein Y<sup>2</sup> is C<sub>1</sub>-C<sub>3</sub> alkylene.

16. The inhibitor of claim 11, wherein Y<sup>2</sup> is C<sub>1</sub>-C<sub>2</sub> alkylene.

17. The inhibitor of claim 11, wherein Ar is substituted or unsubstituted phenylene, which optionally may be fused to an aryl or heteroaryl

5 ring, or to a saturated or partially unsaturated cycloalkyl or heterocyclic ring, any of which may be optionally substituted.

18. The inhibitor of claim 17, wherein the phenylene is 4-phenylene.

19. The inhibitor of claim 11, wherein Cy is selected from the group consisting of phenyl, naphthyl, thienyl, benzothienyl, and quinolyl, any of which  
10 may be optionally substituted.

20. The inhibitor of claim 19, wherein the phenyl, naphthyl, thienyl, benzothienyl, or quinolyl is unsubstituted or is substituted by one or two substituents independently selected from the group consisting of C<sub>1</sub>-C<sub>4</sub> alkyl, C<sub>1</sub>-C<sub>4</sub> haloalkyl, C<sub>6</sub>-C<sub>10</sub> aryl, (C<sub>6</sub>-C<sub>10</sub>)ar(C<sub>1</sub>-C<sub>6</sub>)alkyl, halo, nitro, hydroxy, C<sub>1</sub>-C<sub>4</sub> alkoxy,  
15 C<sub>1</sub>-C<sub>6</sub> alkoxycarbonyl, carboxy, and amino.

21. The inhibitor of claim 11, wherein one or two saturated carbons in L<sup>2</sup> are substituted with a substituent independently selected from the group consisting of C<sub>1</sub>-C<sub>6</sub> alkyl, C<sub>6</sub>-C<sub>10</sub> aryl, amino, oxo, hydroxy, C<sub>1</sub>-C<sub>4</sub> alkoxy, and C<sub>6</sub>-C<sub>10</sub> aryloxy.

20 22. The inhibitor of claim 21, wherein the substituent is oxo or hydroxy.

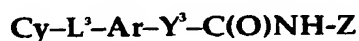
23. The inhibitor of claim 11, wherein no carbon atom of the alkylene is replaced by a heteroatom moiety.

24. The inhibitor of claim 11, wherein one carbon atom of the alkylene  
25 is replaced by a heteroatom moiety selected from the group consisting of O; NR', R' being alkyl, acyl, or hydrogen; S; S(O); or S(O)<sub>2</sub>.



5           25.    The inhibitor of claim 24, wherein  $L^2$  is selected from the group consisting of  $-S-(CH_2)_n-$ ,  $-S(O)-(CH_2)_n-$ , and  $-S(O)_2-(CH_2)_n-$ , wherein  $n$  is 0, 1, 2, 3, or 4.

26.    An inhibitor of histone deacetylase represented by the formula



10    wherein

Cy is cycloalkyl, aryl, heteroaryl, or heterocyclyl, any of which may be optionally substituted, provided that Cy is not a (spirocycloalkyl)heterocyclyl;

$L^3$  is selected from the group consisting of

15           (a)     $-(CH_2)_m-W-$ , where  $m$  is 0, 1, 2, 3, or 4, and  $W$  is selected from the group consisting of  $-C(O)NH-$ ,  $-S(O)_2NH-$ ,  $-NHC(O)-$ ,  $-NHS(O)_2-$ , and  $-NH-C(O)-NH-$ ; and

            (b)     $C_1-C_6$  alkylene or  $C_2-C_6$  alkenylene, wherein the alkylene or alkenylene optionally may be substituted, provided that  $L^3$  is not  $-C(O)-$ , and wherein one of the carbon atoms of the alkylene optionally may be replaced by O;  $NR'$ ,  $R'$  being alkyl, acyl, or hydrogen; S;  $S(O)$ ; or  $S(O)_2$ ;

20

Ar is arylene, wherein said arylene optionally may be additionally substituted and optionally may be fused to an aryl or heteroaryl ring, or to a saturated or partially unsaturated cycloalkyl or heterocyclic ring, any of which may be optionally substituted; and

25            $Y^3$  is  $C_2$  alkenylene or  $C_2$  alkynylene, wherein one or both carbon atoms of the alkenylene optionally may be substituted with alkyl, aryl, alkaryl, or aralkyl; and

Z is selected from the group consisting of aniliny, pyridyl, thiadiazolyl, and  $-O-M$ ,  $M$  being H or a pharmaceutically acceptable cation;

30           provided that when Cy is unsubstituted phenyl, Ar is not phenyl wherein  $L^3$  and  $Y^3$  are oriented *ortho* or *meta* to each other.

5           27.    The inhibitor of claim 26, wherein Z is selected from the group consisting of 2-aniliny, 2-pyridyl, 1,3,4-thiadiazol-2-yl, and -O-M, M being H or a pharmaceutically acceptable cation.

          28.    The inhibitor of claim 27, wherein Z is 1,3,4-thiadiazol-2-yl which is substituted at the 5-position with a substituent selected from the group  
10   consisting of thiol, trifluoromethyl, amino, and sulfonamido.

          29.    The inhibitor of claim 26, wherein Y<sup>3</sup> is selected from the group consisting of -CH=CH-, -C(CH<sub>3</sub>)=CH-, and -CH=C(CH<sub>3</sub>)-

          30.    The inhibitor of claim 26, wherein Ar is substituted or unsubstituted phenylene, which optionally may be fused to an aryl or heteroaryl  
15   ring, or to a saturated or partially unsaturated cycloalkyl or heterocyclic ring, any of which may be optionally substituted.

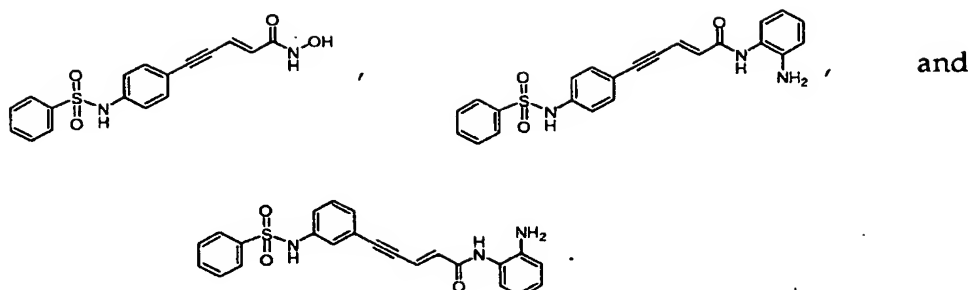
          31.    The inhibitor of claim 30, wherein the phenylene is 4-phenylene.

          32.    The inhibitor of claim 26, wherein Cy is selected from the group consisting of phenyl, naphthyl, thienyl, benzothienyl, and quinolyl, any of which  
20   may be optionally substituted.

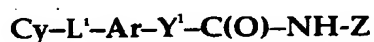
          33.    The inhibitor of claim 32, wherein the phenyl, naphthyl, thienyl, benzothienyl, or quinolyl is unsubstituted or is substituted by one or two substituents independently selected from the group consisting of C<sub>1</sub>-C<sub>4</sub> alkyl, C<sub>1</sub>-C<sub>4</sub> haloalkyl, C<sub>6</sub>-C<sub>10</sub> aryl, (C<sub>6</sub>-C<sub>10</sub>)ar(C<sub>1</sub>-C<sub>4</sub>)alkyl, halo, nitro, hydroxy, C<sub>1</sub>-C<sub>4</sub> alkoxy,  
25   C<sub>1</sub>-C<sub>4</sub> alkoxycarbonyl, carboxy, and amino.

          34.    An inhibitor of histone deacetylase selected from the group consisting of

5



- 10 35. A pharmaceutical composition comprising an inhibitor of histone deacetylase represented by the formula



wherein

- 15 Cy is cycloalkyl, aryl, heteroaryl, or heterocyclyl, any of which may be optionally substituted;

L<sup>1</sup> is  $-(\text{CH}_2)_m\text{-W-}$ , where m is 0, 1, 2, 3, or 4, and W is selected from the group consisting of  $-\text{C(O)NH-}$ ,  $-\text{S(O)}_2\text{NH-}$ ,  $-\text{NHC(O)-}$ ,  $-\text{NHS(O)}_2\text{-}$ , and  $-\text{NH-C(O)-NH-}$ ;

- 20 Ar is arylene, wherein said arylene optionally may be additionally substituted and optionally may be fused to an aryl or heteroaryl ring, or to a saturated or partially unsaturated cycloalkyl or heterocyclic ring, any of which may be optionally substituted;

Y<sup>1</sup> is a chemical bond or a straight- or branched-chain saturated alkylene, wherein said alkylene may be optionally substituted; and

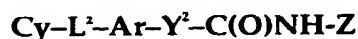
- 25 Z is selected from the group consisting of aniliny, pyridyl, 2-thioxo-1,3,4-thiadiazol-2-yl, and  $-\text{O-M}$ , M being H or a pharmaceutically acceptable cation; and

a pharmaceutically acceptable carrier, excipient, or diluent;

- 30 provided that when L<sup>1</sup> is  $-\text{C(O)NH-}$ , Y is  $-(\text{CH}_2)_n\text{-}$ , n being 1, 2, or 3, and Z is  $-\text{O-M}$ , then Cy is not aminophenyl, dimethylaminophenyl, or

- 5 hydroxyphenyl; and further provided that when L<sup>1</sup> is -C(O)NH- and Z is pyridyl, then Cy is not substituted indolyl.

36. A pharmaceutical composition comprising an inhibitor of histone deacetylase represented by the formula



10 wherein

Cy is cycloalkyl, aryl, heteroaryl, or heterocyclyl, any of which may be optionally substituted, provided that Cy is not a (spirocycloalkyl)heterocyclyl;

L<sup>2</sup> is C<sub>1</sub>-C<sub>6</sub> saturated alkylene or C<sub>2</sub>-C<sub>6</sub> alkenylene, wherein the alkylene or alkenylene optionally may be substituted, provided that L<sup>2</sup> is not -C(O)-, and  
15 wherein one of the carbon atoms of the alkylene optionally may be replaced by a heteroatom moiety selected from the group consisting of O; NR', R' being alkyl, acyl, or hydrogen; S; S(O); or S(O)<sub>2</sub>;

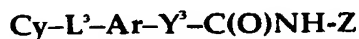
Ar is arylene, wherein said arylene optionally may be additionally substituted and optionally may be fused to an aryl or heteroaryl ring, or to a  
20 saturated or partially unsaturated cycloalkyl or heterocyclic ring, any of which may be optionally substituted; and

Y<sup>2</sup> is a chemical bond or a straight- or branched-chain saturated alkylene, which may be optionally substituted, provided that the alkylene is not substituted with a substituent of the formula -C(O)R wherein R comprises an α-  
25 amino acyl moiety; and

Z is selected from the group consisting of aniliny, pyridyl, 2-thioxo-1,3,4-thiadiazol-2-yl, and -O-M, M being H or a pharmaceutically acceptable cation; and

a pharmaceutically acceptable carrier, excipient, or diluent;  
30 provided that when the carbon atom to which Cy is attached is oxo substituted, then Cy and Z are not both pyridyl.

- 5           37. A pharmaceutical composition comprising an inhibitor of histone deacetylase represented by the formula



wherein

- 10           Cy is cycloalkyl, aryl, heteroaryl, or heterocyclyl, any of which may be optionally substituted, provided that Cy is not a (spirocycloalkyl)heterocyclyl;

L<sup>3</sup> is selected from the group consisting of

- (a)  $-(\text{CH}_2)_m\text{-W-}$ , where m is 0, 1, 2, 3, or 4, and W is selected from the group consisting of  $-\text{C(O)NH-}$ ,  $-\text{S(O)}_2\text{NH-}$ ,  $-\text{NHC(O)-}$ ,  $-\text{NHS(O)}_2\text{-}$ , and  $-\text{NH-C(O)-NH-}$ ; and
- 15           (b)  $\text{C}_1\text{-C}_6$  alkylene or  $\text{C}_2\text{-C}_6$  alkenylene, wherein the alkylene or alkenylene optionally may be substituted, provided that L<sup>3</sup> is not  $-\text{C(O)-}$ , and wherein one of the carbon atoms of the alkylene optionally may be replaced by O; NR', R' being alkyl, acyl, or hydrogen; S; S(O); or S(O)<sub>2</sub>;

- Ar is arylene, wherein said arylene optionally may be additionally
- 20           substituted and optionally may be fused to an aryl or heteroaryl ring, or to a saturated or partially unsaturated cycloalkyl or heterocyclic ring, any of which may be optionally substituted; and

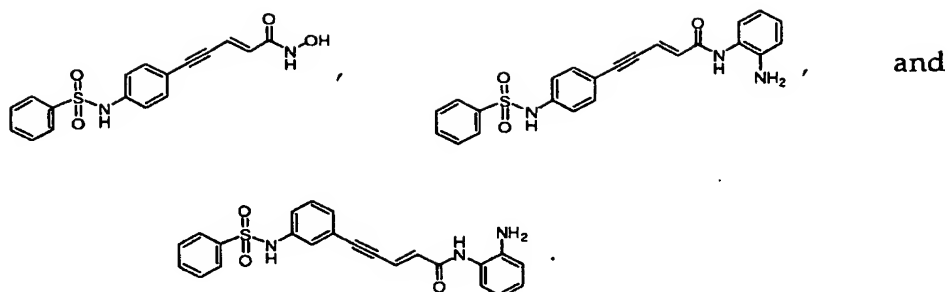
- Y<sup>3</sup> is  $\text{C}_2$  alkenylene or  $\text{C}_2$  alkynylene, wherein one or both carbon atoms of the alkenylene optionally may be substituted with alkyl, aryl, alkaryl, or aralkyl;
- 25           and

Z is selected from the group consisting of aniliny, pyridyl, thiadiazolyl, and  $-\text{O-M}$ , M being H or a pharmaceutically acceptable cation;

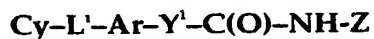
provided that when Cy is unsubstituted phenyl, Ar is not phenyl wherein L<sup>3</sup> and Y<sup>3</sup> are oriented *ortho* or *meta* to each other.

- 30           38. A pharmaceutical composition comprising a histone deacetylase inhibitor of histone deacetylase selected from the group consisting of

5



- 10 39. A method of inhibiting histone deacetylase in a cell, comprising contacting a cell in which inhibition of histone deacetylase is desired with an inhibitor of histone deacetylase represented by the formula



wherein

- 15 Cy is cycloalkyl, aryl, heteroaryl, or heterocyclyl, any of which may be optionally substituted;

L' is  $-(\text{CH}_2)_m\text{-W-}$ , where m is 0, 1, 2, 3, or 4, and W is selected from the group consisting of  $-\text{C(O)NH-}$ ,  $-\text{S(O)}_2\text{NH-}$ ,  $-\text{NHC(O)-}$ ,  $-\text{NHS(O)}_2\text{-}$ , and  $-\text{NH-C(O)-NH-}$ ;

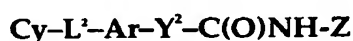
- 20 Ar is arylene, wherein said arylene optionally may be additionally substituted and optionally may be fused to an aryl or heteroaryl ring, or to a saturated or partially unsaturated cycloalkyl or heterocyclic ring, any of which may be optionally substituted;

- Y' is a chemical bond or a straight- or branched-chain saturated alkylene, 25 wherein said alkylene may be optionally substituted; and

Z is selected from the group consisting of aniliny, pyridyl, 2-thioxo-1,3,4-thiadiazol-2-yl, and -O-M, M being H or a pharmaceutically acceptable cation;

provided that when L' is  $-\text{C(O)NH-}$ , Y is  $-(\text{CH}_2)_n\text{-}$ , n being 1, 2, or 3, and Z is -O-M, then Cy is not aminophenyl, dimethylaminophenyl, or hydroxyphenyl.

- 5           40.    A method of inhibiting histone deacetylase in a cell, comprising contacting a cell in which inhibition of histone deacetylase is desired with an inhibitor of histone deacetylase represented by the formula



wherein

- 10           Cy is cycloalkyl, aryl, heteroaryl, or heterocyclyl, any of which may be optionally substituted;

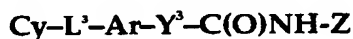
$\text{L}^2$  is  $\text{C}_1\text{-C}_6$  saturated alkylene or  $\text{C}_2\text{-C}_6$  alkenylene, either of which may be optionally substituted;

- Ar is arylene, wherein said arylene optionally may be additionally  
15           substituted and optionally may be fused to an aryl or heteroaryl ring, or to a saturated or partially unsaturated cycloalkyl or heterocyclic ring, any of which may be optionally substituted; and

- $\text{Y}^2$  is a chemical bond or a straight- or branched-chain saturated alkylene, which may be optionally substituted, provided that the alkylene is not  
20           substituted with a substituent of the formula  $\text{-C(O)R}$  wherein R comprises an  $\alpha$ -amino acyl moiety; and

          Z is selected from the group consisting of aniliny, pyridyl, 2-thioxo-1,3,4-thiadiazol-2-yl, and  $\text{-O-M}$ , M being H or a pharmaceutically acceptable cation.

41.    A method of inhibiting histone deacetylase in a cell, comprising  
25           contacting a cell in which inhibition of histone deacetylase is desired with an inhibitor of histone deacetylase represented by the formula



wherein

- Cy is cycloalkyl, aryl, heteroaryl, or heterocyclyl, any of which may be  
30           optionally substituted, provided that Cy is not a (spirocycloalkyl)heterocyclyl;

$\text{L}^3$  is selected from the group consisting of

5 (a)  $-(CH_2)_m-W-$ , where  $m$  is 0, 1, 2, 3, or 4, and  $W$  is selected from the group consisting of  $-C(O)NH-$ ,  $-S(O)_2NH-$ ,  $-NHC(O)-$ ,  $-NHS(O)_2-$ , and  $-NH-C(O)-NH-$ ; and

(b)  $C_1-C_6$  alkylene or  $C_2-C_6$  alkenylene, wherein the alkylene or alkenylene optionally may be substituted, provided that  $L^3$  is not  $-C(O)-$ , and wherein one of the carbon atoms of the alkylene optionally may be replaced by O;  $NR'$ ,  $R'$  being alkyl, acyl, or hydrogen; S;  $S(O)$ ; or  $S(O)_2$ ;

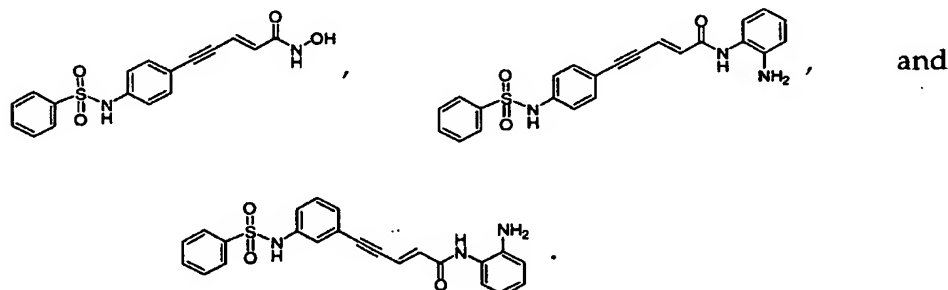
10 Ar is arylene, wherein said arylene optionally may be additionally substituted and optionally may be fused to an aryl or heteroaryl ring, or to a saturated or partially unsaturated cycloalkyl or heterocyclic ring, any of which may be optionally substituted; and

$Y^3$  is  $C_2$  alkenylene or  $C_2$  alkynylene, wherein one or both carbon atoms of the alkenylene optionally may be substituted with alkyl, aryl, alkaryl, or aralkyl; and

20 Z is selected from the group consisting of aniliny, pyridyl, thiadiazolyl, and  $-O-M$ ,  $M$  being H or a pharmaceutically acceptable cation;

provided that when Cy is unsubstituted phenyl, Ar is not phenyl wherein  $L^3$  and  $Y^3$  are oriented *ortho* or *meta* to each other.

42. A method of inhibiting histone deacetylase in a cell, comprising contacting a cell in which inhibition of histone deacetylase is desired with an  
25 inhibitor of histone deacetylase selected from the group consisting of





- 5           43.    The method of any one of claims 39-42, wherein cell proliferation is inhibited in the contacted cell.
44.    The method of any one of claims 39-42, wherein the cell is a neoplastic cell.
45.    The method of claim 44, wherein the neoplastic cell is in an animal.
- 10          46.    The method of claim 44, wherein the neoplastic cell is in a neoplastic growth.
47.    The method of any one of claims 39-42, further comprising contacting the cell with an antisense oligonucleotide that inhibits the expression of a histone deacetylase.
- 15          48.    The method of claim 47, wherein cell proliferation is inhibited in the contacted cell.

## INTERNATIONAL SEARCH REPORT

International Application No

PCT/IB 00/01881

## A. CLASSIFICATION OF SUBJECT MATTER

IPC 7 C07D333/38 C07C311/21 C07D333/62 C07C259/10 C07C321/28  
C07D285/135 A61K31/38 A61K31/18 A61K31/165 A61K31/41

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 7 C07D C07C

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

PAJ, EPO-Internal, WPI Data, BEILSTEIN Data, CHEM ABS Data

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	JP 11 302173 A (MITSUI CHEM INC) 2 November 1999 (1999-11-02)  see table 1, compounds 5-7, 19, 45, 47, 50, 52, 59, 60, 63-67 & English translation of JP-11302173 --- -/--	1,2,6,7, 11,12, 14,17, 18,21, 22,24, 35,36, 39,40, 43-48



Further documents are listed in the continuation of box C.



Patent family members are listed in annex.

## \* Special categories of cited documents:

- \*A\* document defining the general state of the art which is not considered to be of particular relevance  
\*E\* earlier document but published on or after the international filing date  
\*L\* document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)  
\*O\* document referring to an oral disclosure, use, exhibition or other means  
\*P\* document published prior to the international filing date but later than the priority date claimed

- \*T\* later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention  
\*X\* document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone  
\*Y\* document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.  
\*Z\* document member of the same patent family

Date of the actual completion of the international search

6 March 2001

Date of mailing of the international search report

12.04.01

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## INTERNATIONAL SEARCH REPORT

International Application No

PCT/IB 00/01881

## C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	MANFRED JUNG ET AL.: "Amide Analogues of Trichostatin A as Inhibitors of Histone Deacetylase and Inducers of Terminal Cell differentiation" J. MED. CHEM., vol. 42, no. 22, 4 November 1999 (1999-11-04), pages 4669-79, XP002144226 see table 1, examples 5f, 5g	11,12, 14-22, 24,35, 36,39, 40,43-48
X	DATABASE BEILSTEIN 'Online! Beilstein Informationssysteme GmbH; XP002162157 see BRN 3436503, 4265970, 2813528, 7299261, 2890108, 2793974	1,2, 6-12,14, 17-22,24
X	DATABASE BEILSTEIN 'Online! Beilsteininformationssysteme GmbH; XP002162158  see BRN 5634742, 6816677, 2852507, 2855506, 3454395	11,12, 14,17, 19,20, 24,36
X	DATABASE BEILSTEIN 'Online! Beilsteininformationssysteme GmbH; XP002162159  see BRN 6864971, 4446205	11,12, 14, 17-20, 24,25
X	DATABASE BEILSTEIN 'Online! Beilsteininformationssysteme GmbH; XP002162160  see BRN 7655985, 3313150, 3313231	11,12, 14, 17-20, 24,36
X	DATABASE BEILSTEIN 'Online! Beilstein Informationssysteme GmbH; XP002162161 see BRN 3137042	11,12, 14,17, 19,20,23
X	CHEMICAL ABSTRACTS, vol. 91, no. 13, 24 September 1979 (1979-09-24) Columbus, Ohio, US; abstract no. 107818, KATO HIDEO ET AL.: "Substituted acetoxyhydroxamic acid derivatives" XP002162154 see abstract and RN 71284-46-3 & JP 07 936229 A (HOKURIKU PHARMACEUTICAL CO.) 16 March 1979 (1979-03-16)	11,12, 15-20, 24,36
	-/--	

## INTERNATIONAL SEARCH REPORT

Internl Application No

PCT/IB 00/01881

## C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	CHEMICAL ABSTRACTS, vol. 131, no. 8, 23 August 1999 (1999-08-23) Columbus, Ohio, US; abstract no. 97120, KIM, YOUNG BAE ET AL: "Oxamflatin is a novel antitumor compounds that inhibits mammalian histone deacetylase" XP002162155 abstract & ONCOGENE (1999), 18(15), 2461-70,	34,38, 42-48
A	WO 98 55449 A (QUEENSLAND INST MED RES ;FAIRLIE DAVID (AU); PARSONS PETER G (AU);) 10 December 1998 (1998-12-10) page 48; claims; examples	1-48
X	see page 47, third compound from the top	11,41, 43-48
A	CHEMICAL ABSTRACTS, vol. 131, no. 24, 13 December 1999 (1999-12-13) Columbus, Ohio, US; abstract no. 317417, GLICK, RICHARD D. ET AL.: "Hybrid polar histone deacetylase inhibitor induces apoptosis and CD95/CD95 ligand expression in human neuroblastoma" XP002162156 see abstract and RN 174664-65-4 & CANCER RES. 1999 59(17), 4392-99,	26,37, 41,43-48
A	EP 0 827 742 A (UNIV BRUXELLES) 11 March 1998 (1998-03-11) claims; examples	1-48

# INTERNATIONAL SEARCH REPORT

International application No.  
PCT/IB 00/01881

## Box I Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)

This International Search Report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:  
because they relate to subject matter not required to be searched by this Authority, namely:
2. ☒ Claims Nos.:  
because they relate to parts of the International Application that do not comply with the prescribed requirements to such an extent that no meaningful International Search can be carried out, specifically:  
see FURTHER INFORMATION sheet PCT/ISA/210
3. ☐ Claims Nos.:  
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

## Box II Observations where unity of invention is lacking (Continuation of item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. ☐ As all required additional search fees were timely paid by the applicant, this International Search Report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this International Search Report covers only those claims for which fees were paid, specifically claims Nos.:
4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this International Search Report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

### Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest.
- ☐ No protest accompanied the payment of additional search fees.

## INTERNATIONAL SEARCH REPORT

International Application No. PCT/IB 00 01881

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

## Continuation of Box I.2

The initial phase of the search revealed a very large number of documents relevant to the issue of novelty. So many documents were retrieved that it is impossible to determine which parts of the claim(s) may be said to define subject-matter for which protection might legitimately be sought (Article 6 PCT). For these reasons, a meaningful search over the whole breadth of the claim(s) is impossible. Consequently, the search has been restricted to compounds of claims 1, 11 and 26 with the Z=OM, 2-aniliny1, and 1, 3,4-thiadiazoly1. Claim 34 has been searched completely. However, still too many documents were retrieved, which are relevant to the question of novelty, which could not possibly all be cited. Therefore neither the search nor the search report may be considered complete. The cited documents are merely an arbitrary selection. However, all documents for compounds of the aforementioned restricted search related to the desired activity have been cited.

The applicant's attention is drawn to the fact that claims, or parts of claims, relating to inventions in respect of which no international search report has been established need not be the subject of an international preliminary examination (Rule 66.1(e) PCT). The applicant is advised that the EPO policy when acting as an International Preliminary Examining Authority is normally not to carry out a preliminary examination on matter which has not been searched. This is the case irrespective of whether or not the claims are amended following receipt of the search report or during any Chapter II procedure.

# INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No  
PCT/IB 00/01881

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
JP 11302173 A	02-11-1999	NONE	
JP 7936229 A		NONE	
WO 9855449 A	10-12-1998	AU 7751698 A EP 0988280 A	21-12-1998 29-03-2000
EP 0827742 A	11-03-1998	EP 0827743 A JP 10114681 A US 5993845 A	11-03-1998 06-05-1998 30-11-1999